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THE JOURNAL

—OF THE—

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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CHEMICAL SECTION.

Section of Photography and Microscopy.

Joint Meeting, held Thursday, February 18, 1904.

Results of an Investigation of the Durability of Paints for the Protection of Structural Work.

BY ROBERT JOB,
Chemist to the Philadelphia and Reading Railway Company, Member of the Institute.

A former standard practice for a period of about ten years upon the Philadelphia and Reading Railway for painting bridges consisted in the use of three paints, officially known as No. 8, No. 10, and No. 12, respectively. No. 8 was a red body color, No. 10 a brown, and No. 12 a green trimming color. The composition of the three was essentially the same and consisted of about 22 per cent. sesquioxide of iron, with the remainder partly argillaceous gangue and partly hydrated sulphate of lime, each being ground in pure raw linseed oil, and diluted for use with raw linseed oil and our standard japan.

Notwithstanding the similarity of composition, very marked differences were noted in the relative durability in service. No. 8, under ordinary conditions, gave fair protection to steel for about three years, while No. 12, side by side with No. 8 upon the same structure and under identically the same conditions, had at least double the life of the latter. The life of No. 10 paint was intermediate between the others.

Fig. 1 is typical of the condition of our bridges four years after application of these paints. The horizontal railing

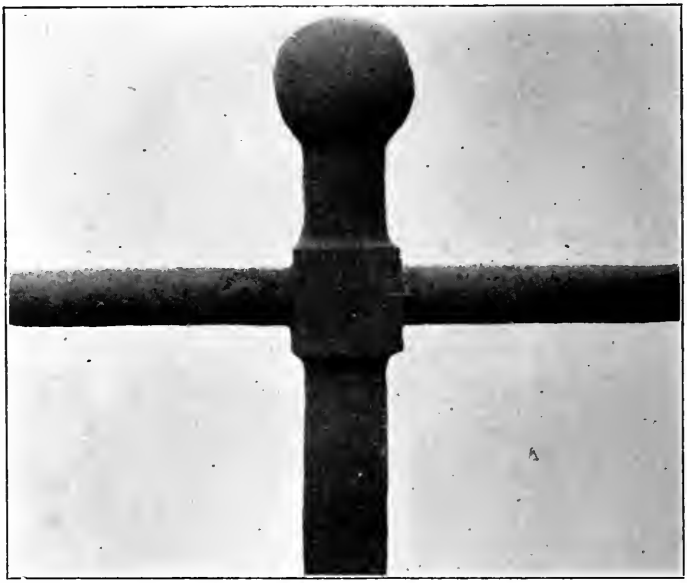

FIG. 1.—Bridge hand-rail and post, showing difference in protective value of two different standard paints after four years' exposure.

was covered with No. 8 paint, and was so badly corroded after four years' service that the paint could easily be detached. The vertical post had been coated at the same time with No. 12 paint, and the entire surface was in good condition after the four years, without a rust spot, and the metal beneath the paint was clean and bright. *Fig. 2* represents a post on the same bridge coated with No. 8 paint,

and it is seen that the metal is badly pitted and covered with rust.

The steel coated with No. 8 paint was very generally pitted and in bad condition, while that painted with No. 12 was well protected and practically free from rust, with clean metal beneath the paint.

FIG. 2.—Bridge column, painted same as railing, Fig. 1. Badly pitted.

No. 10 paint averaged better than No. 8, but was considerably inferior to No. 12.

Having found that the above general results attended the use of these paints over our lines, we began an investigation to determine the causes of the variations, and to work out specifications which would ensure durability at least equal to that of No. 12 paint.

Upon analysis we found the following composition:

	No. 8. Per cent.	No. 10. Per cent.	No. 12. Per cent.
Silica	9·35	17·07	34·10
Alumina	4·44	5·06	19·56
Sesquioxide of iron	21·07	22·74	23·24
Sulphate of lime, hydrated	64·70	52·21	10·66
Alkalies	·44 (by diff.)	2·92 (by diff.)	·49
Water combined with iron and clay,			9·75
Prussian blue			2 10
Carbon black			·32
Free sulphuric acid	None.	None.	None.
Calcium carbonate	None.	None.	None.
	100·00	100·00	100·22
Total water combined			11 88

In a general way each pigment may be said to be composed of about 22 per cent. of sesquioxide of iron and 78 per cent. of inert filler, and the composition shown gives little indication of the cause of the variation in relative durability since practically the same proportion of sesquioxide of iron is present in each, and the fillers used are inert.

We next turned to the physical condition of the pigment, and upon microscopic examination found marked differences.

In No. 8 the largest particles had a diameter of ·0180 inch, there were relatively many of diameter of ·0100 inch, and the diameter of the finest was about ·0002 inch.

In No. 10 the largest particles were about the same size as in No. 8, but there were many fine particles of a diameter of about ·0002 inch, and the average was considerably smaller than that of No. 8, but greater than that of No. 12.

In No. 12 pigment the largest diameter was about ·0010 inch, with very few of that size, and that of the smallest particles was about ·0002 inch, and the whole layer was uniform and exceedingly fine.

As nearly as we could estimate it, the average diameter of No. 8 pigment was about ·0080 inch, while that of No. 12 was about ·0004 inch, considering each particle roughly as a sphere. Volumes of spheres are to one another as the cubes of their diameters, and it follows that the average volume of

a particle of No. 8 pigment was about 8,000 times greater than that of the average No. 12 particle.

The next point to be determined was the effect which the above differences in relative size would have upon the coating in service, and in order to render any differences readily visible, we diluted the paste of each paint with definite proportions of raw linseed oil and standard japan, using our regular batch formula for service work. We then painted vertical glass surfaces with each, and let dry at the ordinary temperature. We then viewed each under the microscope, throwing the light through the glass in such manner as to permit distinguishing each individual particle of the pigment, and again found marked characteristic differences.

In No. 8 paint relatively large oil spaces were present around the particles of pigment.

In No. 10 there was but little such clear space, and in the No. 12 paint the particles were practically touching one another, and were generally piled in several layers deep, thus breaking up the continuity of the oil-film effectively.

Considering the difference previously found in relative size of the three pigments, it appeared evident that the presence of the clear oil-spaces in the case of No. 8 paint were due to the fact that the particles of pigment in that paint were so large that they could not be supported by the oil-film, and therefore gradually dragged down and separated.

In the weathering of linseed-oil paints the oil is gradually acted upon, and the rapidity and extent of such action increases with decreased proportion of pigment in the mixture, as proven by the well-known experiments of Dudley and Pease,* the reason evidently being that as the relative size of oil-films between individual particles of pigment diminishes, the chance for the penetration of water and other rust promoters through the oil to the metal is correspondingly decreased.

From the standpoint of efficiency, it is evidently imma-

* *The Railroad and Engineering Journal*, 1890, page 417.

terial whether relatively large oil-spaces around particles of pigment are due to small proportion of pigment as compared with that of oil, or whether they are due to relative large size of the particles. The result is the same in either case, and a fairly solid and unbroken surface of pigment is not obtainable, as shown above, when the paint is spread in service, and, as a consequence, the elements necessary to cause rusting find comparatively easy access to the metal beneath such coating.

Fineness of subdivision of pigment is of well-recognized importance, and in the many valuable discussions in recent years such condition has been frequently stated to be essential to the best results,* and such expressions coincide with practical experience everywhere. Consequently, the striking variations found in the physical condition of the above pigments gave ample reason for the relative differences in service value.

Up to this point our investigation had shown the nature of the differences in the three pigments. The next step was to find some means by which these differences could readily be seen in practice, and shipments held to the standard of the No. 12 paint.

The ordinary fineness test as formerly made, diluting 5 parts by weight of the paste with 4 parts by weight of raw linseed oil, mixing thoroughly, and placing a few drops of the paint upon a clean dry glass, standing vertical at a temperature of 70° F. for twenty minutes, and specifying that no separation of pigment from oil should result, was found inadequate, for all three paints easily passed such test. We therefore began to increase the severity of the conditions in order to reach the point when the No. 12 paint would just pass the test. After experiment we fixed upon a temperature of 100° F., instead of 70° F., as better adapted to our object, and diluted the paste, which contained approximately 26 per cent. of oil, in proportions of 4 parts by weight of paste to 10 parts by weight of pure raw linseed oil. When diluted in this manner and thoroughly mixed, a few drops

* "Iron Corrosion." Louis E. Andés, page 127, and others.

of the paint were placed upon a clean dry glass and stood vertical at a temperature of 100° F. for one hour. Under this test No. 12 paint showed no signs of separation of pigment from oil, and but slight fading of color on comparing the coating at top and bottom, respectively, of the glass, after the test. Under these same conditions No. 8 paint separated badly and the color at top faded out almost completely; in other words, the greater part of the pigment dragged down, leaving little more than clear oil above. No. 10 paint was intermediate between the others and showed

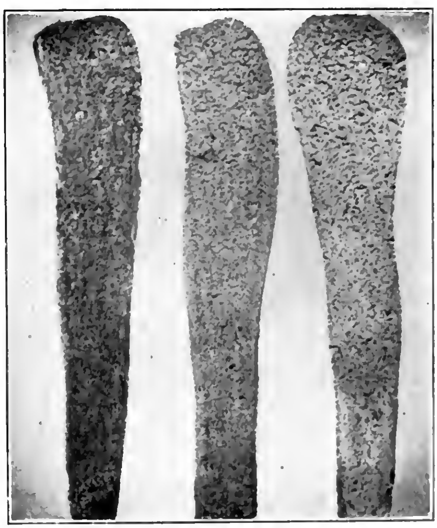

FIG. 3.—Fineness test of three standard paints.
One-half actual size.

some separation and fading, though in much less degree than in the case of No. 8 paint. In *Fig. 3* the fineness test of the three is represented, each containing exactly the same proportions of oil and pigment, and all being placed upon a single slip of glass side by side under the conditions given above.

The photograph was taken upon an illuminated white background, and consequently the larger the proportion of pigment remaining upon the glass after the test, the more complete the shutting out of the light, and the darker the

appearance. No. 12 is upon the left, No. 10 in the middle, and No. 8 at the right. The photograph is one-half actual size.

Having now found the conditions under which these pigments if finely ground would not separate from the oil to an extent noticeable to the unaided eye, we determined the relative fineness of the three pigments by taking photomicrographs of paint on the glass slip, *Fig. 3*, at 100 diameters, at a point in each case ½ inch from the top of the film. *Fig. 4* represents No. 8 paint, and the coarseness of the pigment and the separation of pigment from oil are clearly evident. In *Fig. 5*, representing No. 10 paint, we find a considerable proportion of coarse particles surrounded by a large number of very fine particles, and comparatively small clear oil spaces between the particles. In No. 12 paint, *Fig. 6*, we find very few coarse particles, and an almost unbroken front of very minute particles which almost shut out the bright light immediately behind the microscope. Also, no clear oil spaces are visible in this paint even at this magnification of 100 diameters and at this dilution, and the film was found to consist of particles in several superposed layers, so that practically the entire surface was covered with inert material, and but the barest possible chance offered for the penetration of water and other elements of rust, thus giving a positive answer to the question as to the cause of the relative durability of this paint in service.

Our next step was to build up a pigment having the same properties as No. 12 paint, and this naturally led to a study of the components of the three paints in question. We found that No. 8 paint was composed essentially of calcined metallic brown with hydrated sulphate of lime, in proportions approximately 35 per cent. iron pigment, and 65 per cent. hydrated sulphate of lime.

No. 10 paint consisted of approximately 52 per cent. of hydrated sulphate of lime and 48 per cent. of a natural red sienna, unburnt.

No. 12 paint was composed of natural unburnt ochre, together with about 10 per cent. hydrated sulphate of lime, and 2·4 per cent. tinting material.

Thus, taking the paints in the order of their service values, we note that the greatest durability was found in natural unburned ochre rather low in proportion of sesquioxide of iron (23 per cent.), and with large proportion of clay, and relatively small addition of hydrated sulphate of lime. It is also interesting to note that in this No. 12 pigment, 11·9 per cent. by weight consisted of water, though it was in combination with the clay and sulphate of lime, and not in free condition. The above results thus afford clear proof—in view of the service records—that water, when in proper chemical combination with pigment, does not cause rusting beneath the coating, and also that calcining of pigment is not at all necessary to good service. Upon the other hand, the least durability was found in pigment composed of well calcined material with relatively large proportion of hydrated sulphate of lime; but the lack of durability in that case, as has been shown, was due to the physical condition of the pigment and not to its chemical composition. Hydrated sulphate of lime has been for a long time regarded as an excellent inert paint filler, and our experience has shown that

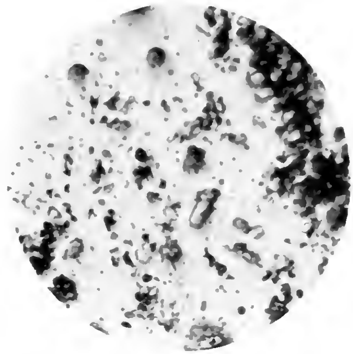

Fig. 4.

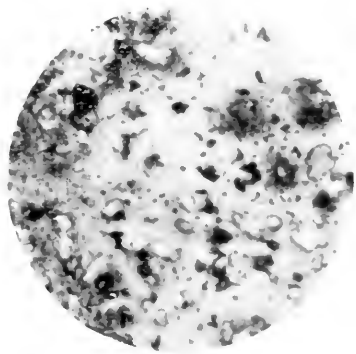

Fig. 5.

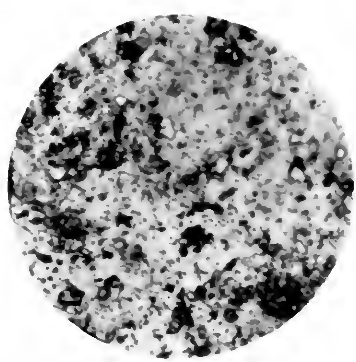

Fig. 6.
Fineness test of standard paints.
(× 100 diameters.)

FIG. 7.

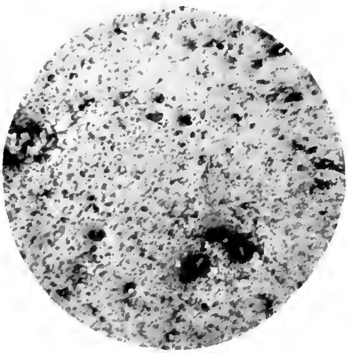

FIG. 8.

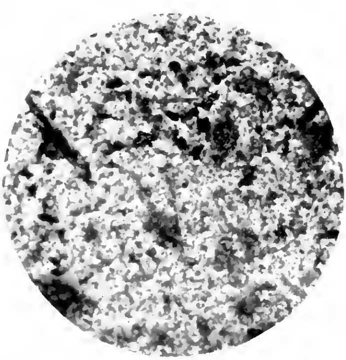

FIG. 9.

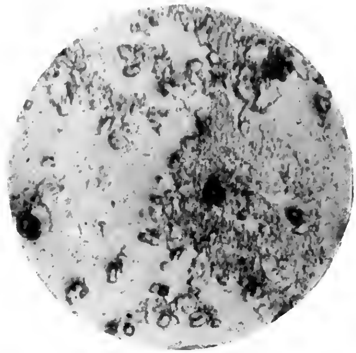

FIG. 10.

FIG. 11.

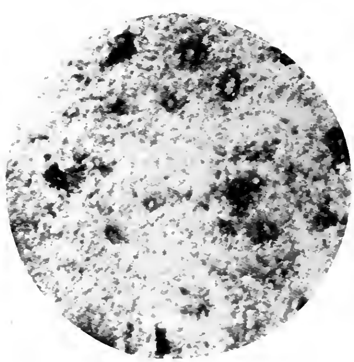

FIG. 12.

Fineness test of "fillers." (× 100 diameters.)

it can be brought to the degree of fineness necessary to enable it to pass the test detailed above, and when in such condition it has given excellent service. We are free to state, however, that the desired degree of fineness can be gained with very much less milling, and hence at lower cost, by use of other materials shown by our service results to be equally inert and durable; but we are perfectly willing to leave the composition of the inert material to the manufacturer, providing merely that it must be inert and of the degree of fineness found necessary and specified.

In order to find out the relative fineness in their commercial form of the various fillers commonly used in paint, we obtained a number of samples, mixed each with the total proportion of raw linseed oil present in the fineness test, *Fig. 3*, subjected it to the fineness test detailed above, and took a photomicrograph at 100 diameters, ½ inch from top of the glass, as in the other cases. *Fig. 7* shows the condition of the finest hydrated sulphate of lime (gypsum) obtainable, and it will be noted that the particles are relatively coarse and granular and are surrounded with large oil spaces. Barium sulphate, *Fig. 8*, is finer to a very marked extent, and the oil spaces, though distinct, are comparatively small. Carbonate of lime (whiting), *Fig. 9*, is one of the finest of the fillers examined, but where exposed to acid fumes is inadmissible. In clay, *Fig. 10*, the majority of the particles are exceedingly fine, though considerable separation has resulted. Silex, *Fig. 11*, contains a relatively large proportion of coarse angular particles, and has also separated considerably. Calcined red oxide had the same general appearance as No. 8 paint, *Fig. 4*. Yellow ochre, *Fig. 12*, was similar in fineness to No. 12 paint, *Fig. 6*, and was the most finely divided of any of the materials examined.

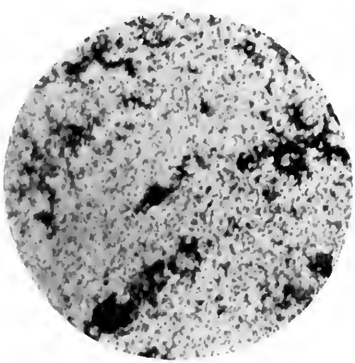

FIG. 13.—New structural paint. (× 100 diameters.)

Fig. 13 represents the condition of our new No. 4 structural paint, at 100 diameters, under the same conditions as in the foregoing. The paint consists of natural soft uncalcined pigment, tinted with a small proportion of carbon black, and ground in raw linseed oil in paste form to pass our standard fineness test. In composition it is essentially the same as No. 12 paint, and, as will be noted, the fineness is even greater than that of the latter (*Fig. 6*).

In conclusion I wish to express my thanks to my assistants, J. B. Young and Charles T. Ressler, for much of the analytical work connected with this investigation. Also, I am indebted to a number of manufacturers of paint for samples specially prepared in working out our standards for structural paints, and for advice and assistance regarding details of manufacture.

READING, PA., February 17, 1904.

DISCUSSION.

MR. CHARLES M. MILLS.—Mr. Chairman: As the durability of paint No. 8 was so inferior to No. 12—No. 8 containing such a large proportion of gypsum—I would ask whether Mr. Job has not found that gypsum is soluble in water, which would tend to explain the destruction of paint No. 8 after the oil had yielded to the atmospheric influences, exposing the pigment to the action of the weather. As a practical matter, in dealing with plaster of paris I have found that it has been sufficiently soluble in water, on one or two occasions, to attract my notice, although I am not a chemist, and am not at this time informed as to the extent to which this material is soluble in water.

Regarding the behavior of paints exposed to the exhausts of locomotives in cases where paints were placed on the under side of overhead bridges, I can state that during my experience with city bridges, while with the Bureau of Surveys of this city, I became convinced that no paint made up to this time, and probably no paint ever to be made, would stand the sand-blast action from the exhaust of locomotives, to say nothing of the gases and heat to which they were subjected when the overhead clearance was low. It

was found that the only way to protect paint exposed to these conditions was to supply sheathing and prevent the direct action of the locomotive exhaust upon the paint. It appeared that wood was the most satisfactory material to use for this purpose, as it seemed to resist the abrasion of the particles of cinders better than metal, having what might be termed a cushion effect, which absorbed the energy in the impact of the particles thrown by the blast against it.

The wood used was white pine, and did not wear away, and to my knowledge never caught fire. Care was taken to have no openings in the sheathing through which large particles of hot cinders could be thrown, which would lodge in crevices of the wood and tend to cause fire.

An examination was made of the sheathing under the bridge over the Philadelphia and Reading Railway at Thirty-first Street and Girard Avenue, and also over the West Chester and Philadelphia Railroad at Forty-ninth Street, after seven years of service. The paint on the bridge over the Philadelphia and Reading Railway was extremely well preserved, the only place where I saw rust was on the corners of some angles and cover plates, where the paint was probably brushed out very thin. At the bridge over the West Chester and Philadelphia Railroad considerable leakage had come down through the floor, and where the water had run over the metal work there was more or less rust. The general condition of the paint on the metal work was good. The paint used on both of these bridges was red lead tinted with lampblack. The sheathing under both of these bridges was entirely closed. It doubtless would have been better for the preservation of the sheathing and also the paint, if some ventilation had been provided for.

The condition of the wood at the Girard Avenue Bridge over the Philadelphia and Reading Railway was excellent, and had retained the paint on the underside of the wood. The woodwork at the Forty-ninth Street Bridge was decayed in some places, doubtless owing to the leakage of water above referred to.

For protection of wooden sheathing exposed as above, I think a paint with an oxide of iron pigment would do as well as anything, but would exclude the use of any paints with pigments of lead and zinc.

MR. HENRY C. STEWART.—Mr. Chairman: I think that the Third Exhibit of Painted Experiments (No. 12) is much more favorable as to lasting qualities, in the ingredients, than either of the others (Nos. 10 or 8). This without reference to the iron contained. Lampblack lasts indefinitely; and clay, owing to its fineness and unctuous characteristics, added materially to the longevity of the pigments.

In regard to the slides showing the deterioration of the oxide of iron extended with gypsum on the painted bridge-upright, the deterioration might have been caused by the pigment having contained free sulphur. The chairman will remember how apt this was to occur years ago when the industry was not understood or the requirements of engineers and the trade so strict as at present.

I remember when a boy, in an interview with the late Col. Samuel Wetherill, the inventor of the American process for making oxide of zinc, that he said he believed a moderate quantity of china clay added to zinc or lead would be beneficial. And I see no reason why it should not be true as to other basic pigments.

Pure oxide of iron is largely used in England for the preservation of structural work, and such practice is undoubtedly built on years (centuries, I might say) of observation, and might be studied by our engineers with profit.

The lasting qualities of pure oxide of iron are similar to those of lampblack. The particles of the pigment being so infinitesimally fine, seem to enter the interstices of the coated object, and so prevent the action of the elements long after the oil has disappeared.

I remember seeing a sign at the southeast corner of Front and Arch Streets, Philadelphia, which had been painted some time between 1776 and 1800, and it was still in good condition in 1876, as far as the lettering of the names was concerned. The wood-work surrounding the names (which were painted with lampblack) had eaten away

to the extent of $\frac{3}{8}$ of an inch. As an object lesson it was very remarkable, and certainly demonstrated the worth of the lampblack upon wood.

MR. ALBERT LUCAS.—Mr. Chairman: I would like to ask whether there was any more noticeable fading of the No. 12 color, containing ocher, than in the other colors—No. 8 and No. 10. The question is raised on account of the fact that we have found by practical experience that paints containing a considerable percentage of ochre have a tendency to blacken or discolor, and I thought that this might possibly be due to the hydration of the ochre, whereby one of the darker oxides of iron would be formed in the paint.

As I understand the chairman's statement, he inferred that the best paints were only those which were composed of compounds which formed insoluble salts with linseed oil and that the presence of various amounts of "fillers" was due to a desire on the part of the manufacturer to increase his profits in the same manner as producers of olive oil, added thereto a certain amount of cottonseed oil as a "filler." I wish that Mr. Job would set the chairman straight regarding the use of so-called "fillers" in paints, and reiterate what has been so clearly demonstrated in the paper, that the presence of a percentage of certain inert, finely ground pigments is not injurious; but, on the contrary, helps to increase the durability and decrease the cost of paints.

Permit me to add that the paper is the clearest and most logical demonstration of the question I have ever heard.

MR. JOHN GRUNDY:—My experience has been that where pure oxide of iron paint (finely ground) is used, and the best linseed oil only, iron would be much better protected than with a pigment containing much calcium sulphate (gypsum). I take it that the reason why No. 12 paint was more durable than No. 8 was because the former had little calcium sulphate and more silica and alumina in a fine state of division. I have always found a finely ground pure iron oxide and good linseed-oil paint was the best for iron work, and I also always found that calcium sulphate, no matter how finely ground, "was like sawdust." I can state that I have always

had an objection to using any kind of lime as a base, as from experience I have found that paint containing calcium sulphate would not stand water, and paint containing calcium carbonate would not stand acid fumes. I have seen a marble tombstone (carbonate of lime) eaten half way in ten years in a cemetery near a chemical works. French ochre and some English ochres containing silica and alumina in a natural fine state of division are good preservatives, while American ochre does not seem so good, as it is naturally very coarse, and when ground seems to contain much free iron ore, which both destroys the shade of the pigment, and also allows the elements and sulphur fumes to act readily on it.

MR. EDWARD T. LONGSTRETH:—I have always held carbonate of lime to be one of the best extenders for paints, for the following reasons: Paris white is the best grade of carbonate of lime that comes into the market for use in the manufacture of paints. This article is produced first by grinding the chalk with water under heavy runners, and the mixture is pumped into a series of vats through which it flows from one to another, leaving a deposit in each. The last vat contains the finest and purest grade of chalk, which is called American paris white.

This product after being allowed to settle, the surplus water is drawn off and the product allowed to dry until it is in condition to be dug out and put in the dry kiln, where steam heat is used to drive off the balance of moisture, after which it is powdered and bolted, when a product of a soft velvety texture and of good body is the result.

The combination of paris white with any color adds a softness to the mass, which, when thinned ready to be brushed upon a surface, flows freely under the brush and leaves a smooth finish.

Pound for pound, paris white used against any other of the pigments that are employed as extenders produce a product of greater body, fineness of texture, also greater bulk, which necessarily means increased covering capacity, and, as paint in paste form is sold by the pound, the deduction naturally is that a paint of the proper density of body and of

greatest bulk will at the same cost be the cheapest product, as thus the covering capacity is greatly increased. Take, for example, two pigments that have been extended 100 per cent., one with carbonate of lime and the other with sulphate of lime; the former will not only be of greater bulk and of better covering properties than the latter; but, with the same amount of thinners, will cover more surface at a less cost per square foot.

Paris white is very durable, as, when mixed with pure linseed oil, it will withstand the action of the elements for some years. Take as example the putty with which we glaze our window-sash (this article is made from the same material as the paris white, although of a coarser grade) and you will note the number of years it will stand, even if unprotected with paint.

Mr. Walter S. Davis.—Mr. Chairman: As to the effect of water combined with the pigment upon service value, my experience also has been that it is not deleterious or objectionable. I have found, too, that its exclusion very materially impaired the working qualities of the paint, and this, I believe, was practically tested and fully verified by Dr. Dudley some years since.

All of the discussions of the evening have confirmed the opinion expressed in the paper regarding the grinding of sulphate of lime to a point where its granular appearance would not be so marked. Its structure, as we know, is different from clay. There is no amount of milling that will take it out of its granular condition, while clay can be readily milled to where it produces a plastic rather than a granular coating. The plastic coating is certainly the desirable one for the exclusion of moisture, as was so completely evidenced by the photomicrographs showing the No. 12 paint.

Mr. W. B. Reigner:—Referring to the method used some years ago, to protect the metal work of the bridge carrying Broad Street and Lehigh Avenue over the Reading Railway, a plaster coat about ½ inch thick was applied to corrugated iron lath which was laid on light metal framework attached to the bottom flanges of the girders, the entire

under-surface of the structure being thus closed against the action of the locomotive fumes. The construction was not satisfactory, owing to its not having sufficient strength to withstand the force of the exhaust from engines. The clearance above the rail was only 16 feet, and there is a grade in the track which gave increased effect to the exhaust. In a short time the plaster became loose and began to fall upon the track, requiring the whole to be removed. Had the construction been of sufficient strength, it would doubtless have answered its purpose for a considerable time.

DR. HENRY LEFFMANN:—I have always understood that the durability of a paint is largely dependent on the formation of compound by the action of the oil upon the admixed solid material. This compound is of the nature of soap and its formation involves the oxidation of the oil to acidulous bodies. Hence, the best materials for admixture with oil will be those mildly basic, and capable of forming soaps that are insoluble in water. The opacity of the solid matter influences the covering power of the paint, which is of considerable practical importance. These qualities are possessed in a high degree by white lead. It has been held by most experts in this field that white lead in linseed oil is the best paint. I have always thought that gypsum found its way into paint only as an adulterant, and that ferric oxide is used as a cheap substitute for white lead, although, of course, color requirements often necessitate a departure from the white-lead-linseed-oil mixture.

From a theoretic point of view I would regard barytes as superior to gypsum, as the latter is slightly soluble in water, and decomposed by ammonia carbonate, which may be present in rain-water.

MR. JOB:—As to solubility of gypsum, Watts states that it is very slightly soluble in water, different authorities varying from 1 part gypsum in 400 parts water, to 500 parts water. Hurst gives the solubility as about 1 part in 500 parts of water, and states that upon exposure to light and air, gypsum is unaffected, being one of the most permanent pigments known. ("Painters' Colors, Oils and Varnishes," page 80, second edition.) It is undoubtedly true, we

think, that this slight solubility shortens somewhat the effective protection where gypsum is present in large proportion in the pigment, but where the proportion is moderate the influence would probably be very slight, since each particle if properly ground would be protected by the other inert matter, and thus the ordinary slight solubility would be very much lessened.

It is of course perfectly possible that the poor service of No. 8 paint may have been due to a slight extent to the solubility of the sulphate of lime, but in the case of No. 10 paint we have nearly as large a proportion as in No. 8, but far better service. Moreover, in our service we have had under long exposure paints which contained fair proportions of sulphate of lime, and the durability of the coating has been good in cases where the fineness was of the degree stated in the paper.

We fully concur in the experience of Mr. Davis and Mr. Grundy as to the difficulty of getting the desired degree of fineness with this pigment, but in our specifications for Structural Paints, to which reference has been made, we have not barred out sulphate of lime provided it is ground finely enough to pass our fineness test. As a matter of fact, however, very little, if any, gypsum will be found in these shipments, since it is practically shut out, from the standpoint of the manufacturer, by the cost of milling it to the degree of fineness specified.

As to carbonate of lime, our results have shown that it is inadmissible where exposed to acid fumes—as strikingly illustrated by Mr. Grundy. In our black car paint, used upon coal cars, we have, however, specified from 10 to 15 per cent. of whiting in order to increase the fineness of the sulphate-of-lime base, and the results have been fairly good, but we shall probably revise this practice and gain increased fineness by use of other materials and thereby increase the durability without increasing the cost of the paint.

In reply to Mr. Lucas, I can state that the degree of fading of the three paints was slight and about the same. There was a slight lightening of the shade in each case on long exposure.

In order to get the effect of exposure and warmth upon the pigment itself without oil, we spread out a layer of each pigment in a large watch glass, and kept upon the steam table at a temperature of 150° F. for about two weeks, we then mixed with oil and made comparison under glass with the original pigment also rubbed up in oil. In each case we found a slight lightening of the shade, about the same as found in service. The darkening mentioned by Mr. Lucas might perhaps be due to partial dehydration, though it seems unlikely that a temperature sufficiently high to effect this change would be met in ordinary service. Possibly the action of sulphur fumes may have had an influence.

As regards the question of inert matter, we can do no better than quote the important papers of Dudley and Pease, to which reference has already been made: * "All we can say is that we try to use as much pigment which from its nature is chemically inert, and as little pigment which is chemically active, as possible. To our mind, the well known fact that white lead mixed with barytes or other inert material lasts longer than pure white lead is explained on the supposition that the white lead combines chemically with the oil, forming a chemical body which is not as durable as dried linseed oil with an inert pigment." And again: † "A mixture of two pigments of good and inferior covering power can be made which will give almost if not quite as good covering power as if the paint was made wholly of the better pigment."

‡ "The law, as we understand it, is this: 'you may use as much inert material as will leave good optical covering power when the paint is properly mixed and applied.'"

The above is clear and to the point, and is in thorough accord with the teachings of our service results in cases where the pigment was of the degree of fineness stated in this paper, and it will be noted that our No. 12 paint, which gave excellent service, was composed of 75 per cent.

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* *American Engineer and Railroad Journal*, September, 1890, page 416.

† *American Engineer and Railroad Journal*, February, 1891, page 82.

‡ *American Engineer and Railroad Journal*, April, 1891, page 176.

of inert matter, and only 25 per cent. of material even slightly chemically active. As has been shown above, the difference between success and failure in the service of such paint ground in pure linseed oil and properly applied lies in the mechanical condition of the pigment—a matter which can be easily regulated.

As to the composition of No. 8, No. 10 and No. 12 paints, we agree with Mr. Stewart that that of the latter is the most favorable of the three, due to the presence of the larger proportion of clay, the cause being, we think, not any especial virtue in clay itself, but the fact that clay of good quality consists of matter chemically inert, practically insoluble and in an almost impalpable state of fineness, and consequently it is in a condition from which efficiency would be expected even without milling. In the No. 12 paint no lampblack was present, and only 0·2 per cent. of carbon black—too small a proportion to have any influence upon the service. Careful test was made of each pigment, but no free sulphuric acid was found.

When exposed at short range to the sand blast of exhaust of locomotives, our experience tallies with that of Mr. Mills, for we have found no paint which has great durability under such conditions. It is possible that reinforced concrete may bring a solution of this problem.

Through the kindness of Mr. Stewart we received samples of pure red oxide pigments such as used abroad upon structural work, and found that one sample, containing 97·50 per cent. sesquioxide of iron, fully met our requirements for fineness, and was of very good quality throughout. Such a pigment, if properly prepared, would without question give good service results. Our main criticism would be that it would cost more and would probably give less efficient service than if diluted with sufficiently fine inert matter of good quality. Cost of paint is an important matter of consideration to the large consumer, and one fact clearly emphasized by this study is that durability and low cost can be made coincident.

Dr. C. B. Dudley (correspondence):—If I understand the matter rightly, the point which Mr. Job has apparently

developed, is that fineness of the pigment is a very important element in the durability of the paint. We believe very few will object to this view, and it looks to us as though this paper is a decided call on the paint manufacturers to give us finer pigments.

In this connection it may not be amiss to say that for a long time it has been out belief, supported by some experimental evidence, that pigments can be made fine in the dry condition much cheaper than they can after they are mixed with the oil. In other words, the making of pigment fine should precede the mixing with the oil, and the mill, which has heretofore been used to make the pigment fine, should be used simply as a means of mixing the pigment and oil together. With some of the devices which are now on the market for getting fineness, it has for some time impressed us that the paint people were not living up to their advantages in the matter of making pigment fine.

One point further. While we all agree that it is advantageous to have the pigment in paint very fine, it should be remembered that the finer the pigment the slower the paint dries, and that, of course, there is a point which cannot be exceeded without running into the difficulty of slow drying. Our experience with the paints in the market, however, indicates that we are very far short of that point at the present time.

MR. JOB:—Dr. Dudley's belief that pigments can be made fine in the dry condition much cheaper than they can after they are mixed with oil is directly in line with our own experience, and, as referred to in the paper, we have found that the desired degree of fineness can be obtained with very much less grinding, and hence at lower mill cost, by use of inert materials which occur in a natural state of extreme fineness, and hence require little more than thorough mixing with oil of good quality to make into serviceable protective paint, and such materials can be obtained upon the open market at relatively low cost. We have also found that pigment of less initial fineness can be brought to the desired condition more economically by grinding without addition of oil, the reason being, we take it, that when oil is

present its viscosity prevents the milling surfaces from coming into close contact, and hence shuts out the chance for the degree of fineness of pigment otherwise obtainable.

Fineness of pigment certainly has a decided influence upon time of drying, as, for instance, in pure lampblack paint (to cite an extreme case); but with the ordinary inorganic pigment, the degree of fineness is so far below the latter standard that not the slightest difficulty due to slow drying is found when the pigment is even finer than in the No. 12 paint referred to above. In use of that paint, a dry coating could be obtained in eight hours when necessary, but we think it better practice to use the minimum proportion of japan and allow a longer time for drying.

COMPARATIVE COST OF WATER POWER.

The cost of water power development in France, according to Professor Janet, varies from $21.40 per horse-power to $150 per horse-power, depending on the head to be dealt with, the lowest expenditure being upon a fall of 140 meters in Haute-Savoie, the horse-power being calculated at the turbine shaft. At Geneva, for the first group of turbines erected, of 840 horse-power, and for the river works then completed, the capital cost amounted to $300 per effective horse-power. The groups of turbines subsequently erected cost but $95 per horse-power, and the completed works would cost but $135 per horse-power. At the chlorate works at Valorbe, the capital expenditure upon the development of 3,000 horse-power amounted to only $19.45 per horse-power. At Niagara, the rates charged to ordinary consumers by the Cataract Power and Conduit Company varied from 2 cents per unit for 1,000 units per month or less to 0·64 cent. per unit for 80,000 to 200,000 units per month. The cost of energy for power purposes from water-power stations in France and Switzerland varied from 2·1 cents per unit for small powers to 1·24 cents per unit for large powers.

THE ELMORE COPPER WORKS AT SCHLADERN.

The electrolytic copper-tube works at Schladern, Germany, employing the Elmore process, are turning out about 1,500,000 kilograms of copper tubes a year (*Oesterreichische Zeitschrift fur Berg- u. Hüttenwesen*, December 19, 1903). The precipitation is effected in lead-lined wooden boxes, 6 meters by 2 meters broad, the bottoms of which are first covered to a depth of 200 millimeters with granulated copper, and which are then filled with a solution of copper sulphate containing 3 per cent. of free sulphuric acid. Each box is provided with one or more horizontal spindles placed about 30 millimeters above the layer of granulated copper, which receive a rotary motion from a

shaft under the boxes. The electric current is transmitted to the metallic copper, passes through the solution to the spindles and is then conducted to the next box in the series. The current strength averages 200 amperes at from 40 to 50 volts. All sizes of tubes up to 2·5 meters in diameter and 6 meters long are made. They are said to be remarkably uniform as regards strength, and are fully equal in this respect to cold-bored tubes.

DECLINE OF METALLIFEROUS MINING IN GREAT BRITAIN.

In the course of his review of mine company registration during 1903, appearing in the London *Mining Journal*, Mr. Edward Ashmead points out that only five small companies appear in the list for Cornwall, and he then proceeds to say:

"The most deplorable thing in connection with mining is the low ebb to which British metalliferous mining is reduced. From being one of the most flourishing of industries, it has dwindled down to almost the vanishing point. Great Britain never claimed to be a gold-producing country, but for tin, copper, lead and zinc it was, within the memories of many of those living, able to produce, not only all of these metals required for home use, but even to export part of its production to foreign countries. For some time now Great Britain has been gradually closing down its own mines, and helping somewhat largely to find the means to open those in other countries. According to the mineral statistics of the United Kingdom, compiled by the late Mr. Robert Hunt, we had in the year 1881 no less than 95 mines working and producing tin (all in the two western counties), 68 producing copper, 250 producing lead and 50 producing zinc, making no less than 463 mines producing these four metals alone. The product of these mines not only added directly to the wealth of the nation, but gave honest and constant employment to thousands of hands. Turning to my own tables, I find that in the three years 1881–3, 166 companies for working metalliferous mines were registered at Somerset House, having a total capital of £7,726,566. Twenty years later, 1901–3, only 36 companies were registered, and the united capital fell to £1,044,350."

NEWEST ADDITIONS TO THE U. S. NAVY.

The three 16,000-ton battleships recently authorized by Congress are to have the following dimensions: Length between perpendiculars, 450 feet; length over all, 456 feet 4 inches; extreme breadth, 76 feet 8 inches; depth, 46 feet; draft of water, 24 feet 6 inches. The hull will be plated with ½-inch steel, with a double bottom. A cofferdam 7 feet high and 30 inches wide, filled with corn pith cellulose, and located back of the armor belt, protects the water line. The power equipment includes twelve water-tube boilers, having a total heating surface of 46,750 square feet, and a grate surface of 1,100 square feet; they will carry a pressure of 265 pounds to the square inch. Two triple expansion engines with four cylinders each will drive the vessel at a speed of 18 knots. The cylinders will be 32½, 53, 61 and 61 inches in diameter by 48-inch stroke. The total power of both engines, at 120 revolutions per minute, is 16,500 horse-power.

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, November 18, 1903.

The Utilization and Disposal of Municipal Waste.

By Wm. F. Morse, Sanitary Engineer, New York City, N. Y.
Member of the Institute.

(*Concluded from vol. clvii, p. 423.*)

CREMATION OF WASTE IN THE UNITED STATES.

The beginning of garbage cremation in the United States was made at *Governor's Island in New York harbor* about 1877, when an officer of the army caused to be built a rectangular brick structure with a chimney in the back connected with the interior of the furnace. Only kitchen waste was consumed in this crematory, being deposited upon two slanting iron grates. The fire-boxes of the furnace were placed below and between the grate bars. This primitive crematory has been in use, with some changes and many repairs, ever since it was built, and is only now about to be replaced by a destructor of modern type.

In 1877 Andrew Engle, of Des Moines, invented what was known as the *Engle Cremator*, which in its simplest form of construction was a square brick structure, its height and width nearly one-third of its length. This furnace had transverse grate bars and a fire-box at each end. In the upper chamber the material to be consumed was placed on the transverse bars, and the main fire was supplemented by a secondary fire at the other end of the furnace. This principle of the secondary fire is common to all crematories of the American type. The Engle crematory reached its highest point of development at the World's Fair at Chicago in 1893, where two furnaces of this type destroyed all the garbage and sewage sludge resulting from the presence at the Fair grounds of over twenty-seven million persons during the six months of the Exposition. The work was performed in a perfectly efficient and sanitary manner, but it was ex-

pensive because of the peculiar conditions, and of the nature of the waste destroyed.

About fifty crematories of the Engle pattern were built, some of which are still in use; the most notable example being at *Norfolk, Va.*, where in ten years 60,000 tons of kitchen waste have been consumed at the cost of 50 cents per ton, including all charges for fuel, labor and repairs.

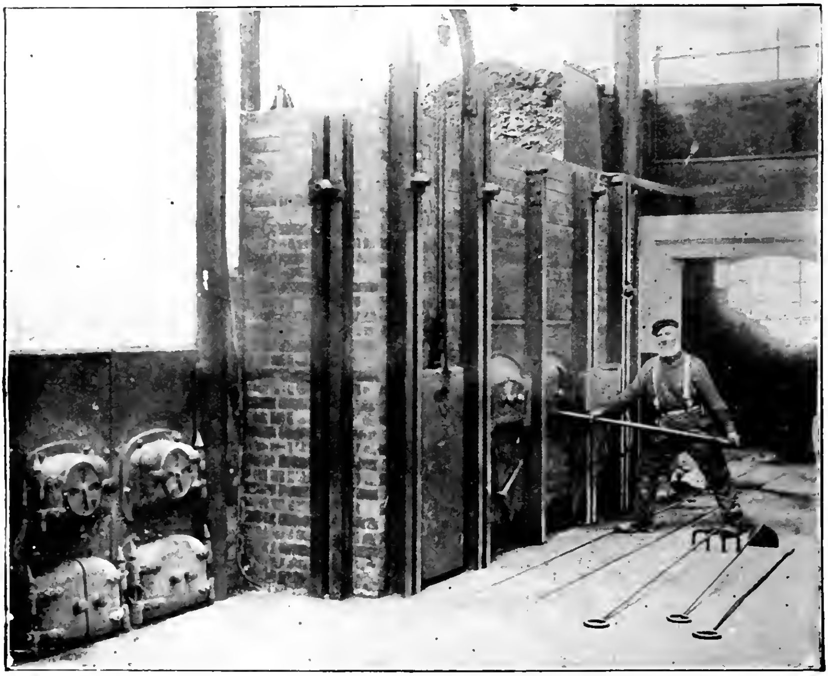

FIG. 10.—Clinkering Meldrum destructor, Llandudno, England.

The *Dixon Sanitary Crematory* originated in Finlay, O., in 1894. In its original form it was an imitation of the Engle furnace. Under new patents the construction was subsequently changed, but it preserved the original features of two grates and three fires for the destruction of the garbage and the gases therefrom. Some thirty examples of the Dixon crematory have been constructed, not all of which are now in use.

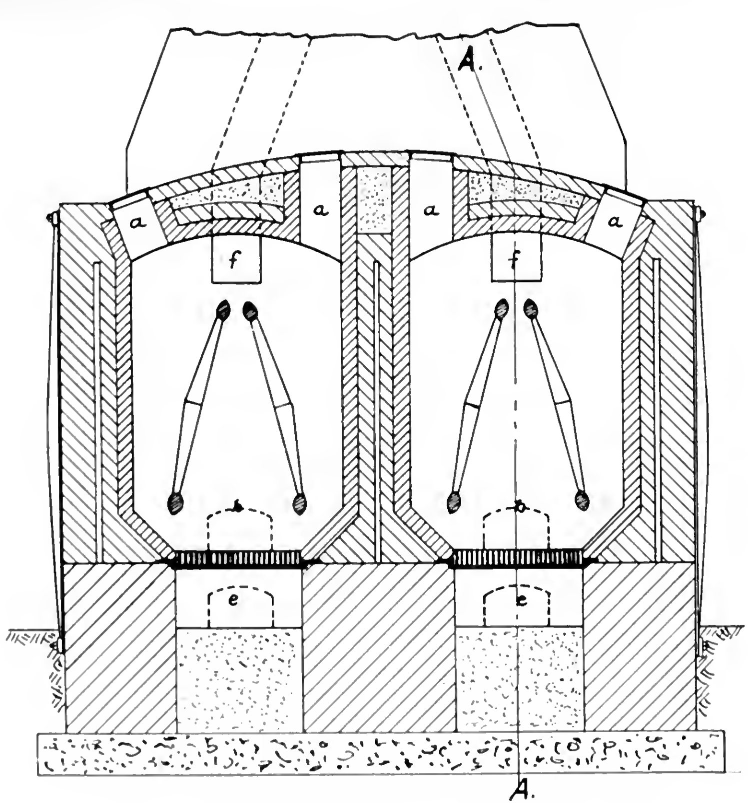

FIG. 11.—First crematory built in United States, 1877–78.

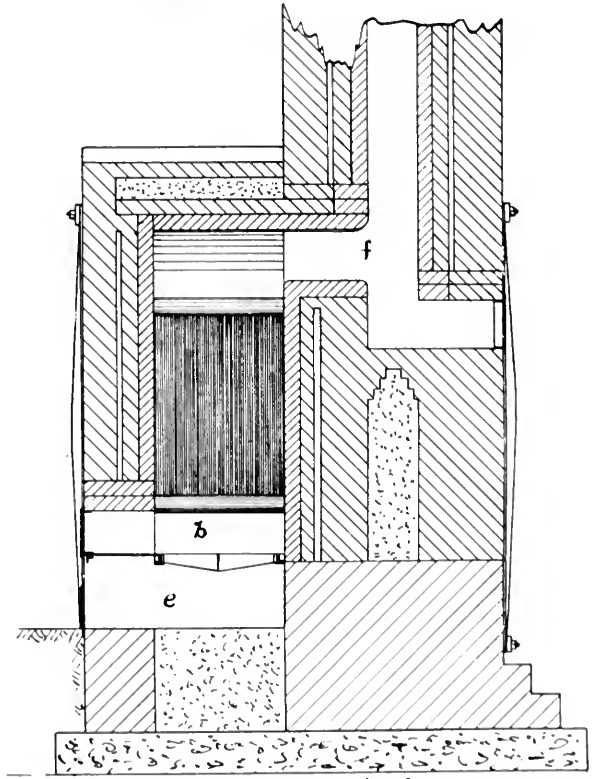

FIG. 12.—First crematory, United States. Section.

Following the same lines of invention came the *Smith-Siemens*, of which one installation is now operating; the *Vivartas Cremating Furnace*, with one example operating; the *Brownlee Crematory*, with one example; the *Thackeray Incinerator*, with two examples operating; and the *Decarie Garbage Incinerator*, with one furnace in active operation. The roster of cremating furnaces built in this country for municipal purposes includes, down to the present time, something like seventy-five to eighty examples, and covers a period of seventeen years. Only about forty of these installations are operating at the time of writing. The list of the names of inventors includes many who, confident of the powers of their inventions, have succeeded in persuading city governments to erect experimental plants, the majority

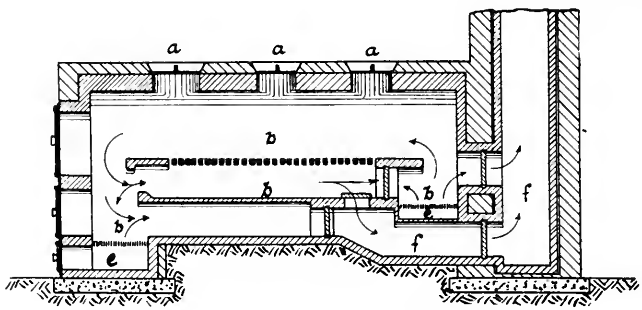

FIG. 13.—The Engle cremator, 1887.

of which have been failures—the failures, in fact, keeping pace with the number of installations accomplished.

PRESENT SITUATION IN THE UNITED STATES.

To day we are almost exactly in the same position as the English towns were in before the adoption of their present methods of disposing of waste by the aid of forced draft. The American cremating furnaces operating under natural draft can attain only a low temperature, and must do this by the use of fuel in considerable quantities.

Another, and perhaps the chief, reason for the slow progress made in the art of waste disposal in this country, is the fact that municipalities allow the work to pass into the hands of contractors, or corporations, who look at the

matter from a financial viewpoint only. There is no doubt that contractors can usually do the work more cheaply than the city can do it, and that when they are given an opportunity for the performance of this work for a term of years they are in a position to do it for considerably less than the city possibly could. It is their policy, however, to do as little work as possible and to get as much money for it as they can.

Again, the initial steps in disposal work are usually taken by the gentlemen of the City Councils and the Health

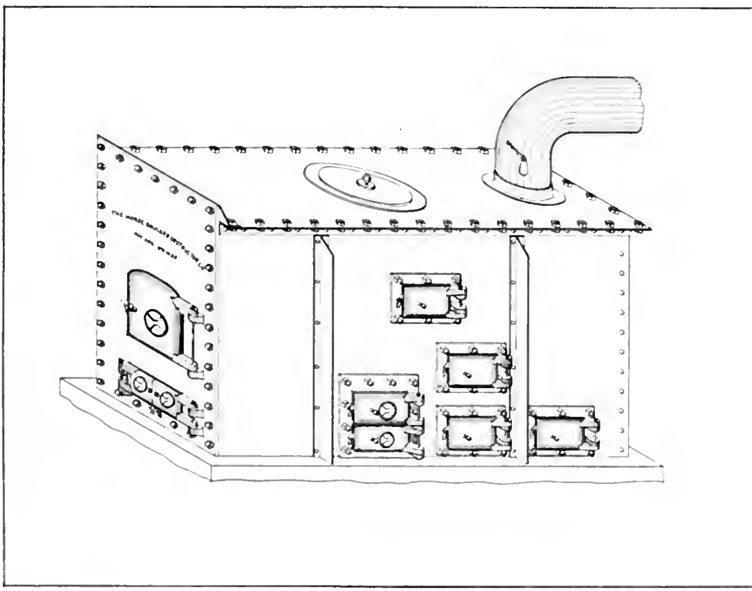

FIG. 14.—Morse-Boulger destructor, 1895–96 (small size). Standard No. 1.

Department, who are usually without the technical education and experience necessary for the correct solution of an engineering problem of this character, and who have to accept estimates made for them without having the benefit of previous knowledge, or of expert advice. Probably to this fact alone are due a large part of the failures of crematories that have occurred in this country. It is obvious that if any substantial progress is to be made, there must be radical changes in the methods of construction and in the

development of engineering skill, and a more intelligent examination of the methods which it is proposed to employ.

DEVELOPMENT OF INSTITUTIONAL DESTRUCTORS.

There is another side to the matter which is being developed more rapidly than any other phase of the disposal question. This is the disposal of the waste of large build-

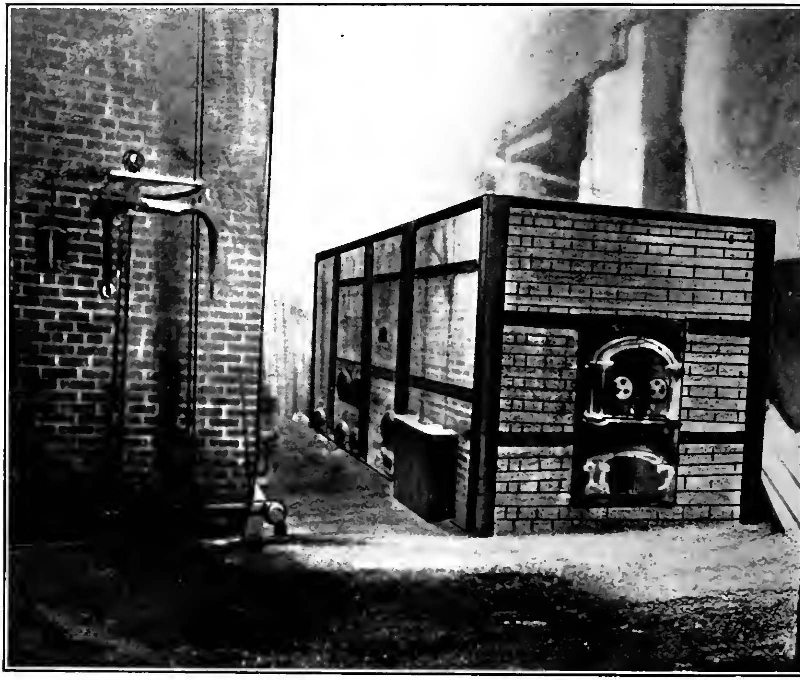

FIG. 15.—Morse-Boulger destructor, with Green's economizer, Lit's department store, Philadelphia.

ings such as hotels, hospitals and sanitariums, business establishments such as department stores and factories, and private buildings. It has been found practicable to install destructor furnaces of sizes proportionate to the amount of waste produced in the building, to be operated by the engineers and firemen regularly employed in the boiler room of the establishment. The heat derived from the cremation of the waste is applied to the production of steam power for

the purpose of heating feed water for the boilers, or for any other purpose of the machinery equipment.

A Morse-Boulger Destructor is installed in one of the largest department stores in Philadelphia. The waste is

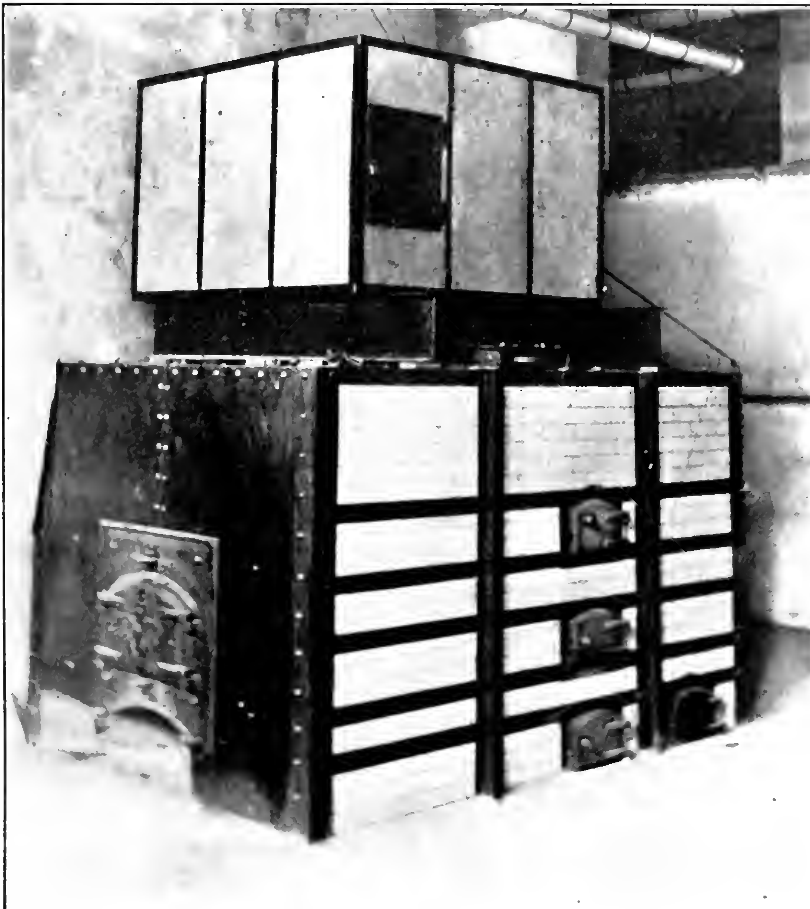

FIG. 16.—Morse-Boulger destructor, Broad Street Station, Penna. R. R., Phila.

brought from the upper floors of the building through chutes to a room in the basement, and after preliminary sorting and recovery of the more valuable portions the remainder is charged into the furnace. The heat derived

from combustion of this waste is passed into a Green's Economizer which heats the feed water of a boiler battery

Fig. 17.—Morse-Boulger destructor, U. S. Navy Yard, Philadelphia. Exterior.

of 750 horse-power, raised by this means to a temperature of 280°.

This example demonstrates the utilization of heat generated by the combustion of worthless refuse, and is a striking instance of the utility of a method which saves practically from 2 to 3 tons of coal per day. The heat may also be utilized by the addition of a steam boiler to the destructor, the power from which is used as auxiliary to the main steam plant, or for independent purposes. Some of

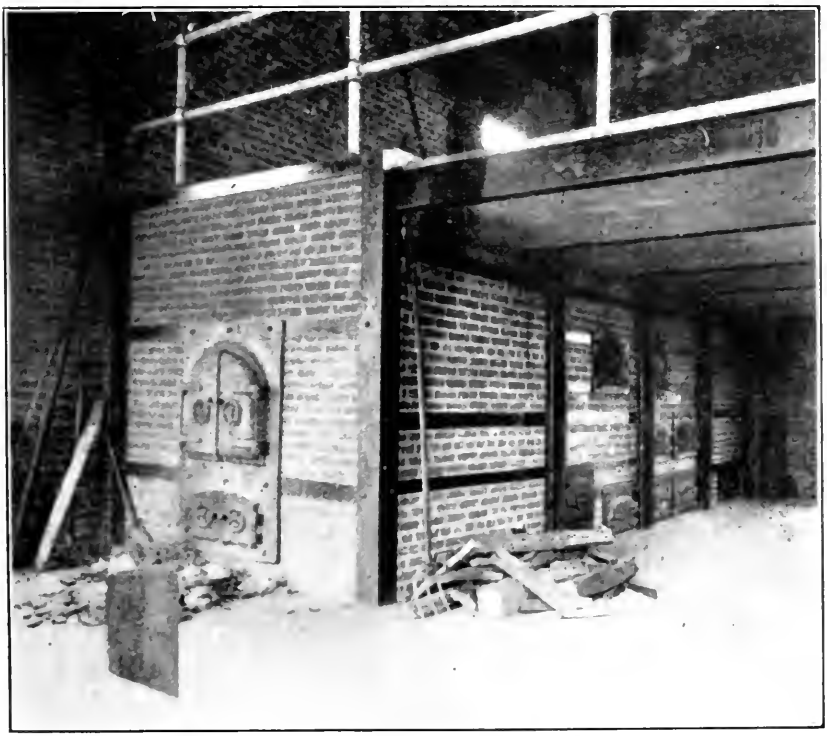

FIG. 18.—Morse-Boulger destructor, U. S. Navy Yard, Philadelphia. Interior.

the largest hotels in this country have adopted this method of heat utilization.

The United States Government has recognized the value and efficiency of these destructors, and has installed them in navy yards, army posts, sanitariums and hospitals, and at the Immigrant Station in New York harbor. At the present time something like sixty examples of the Morse-

Boulger Destructor form of construction are operating, and are used for the disposal of waste of every character,

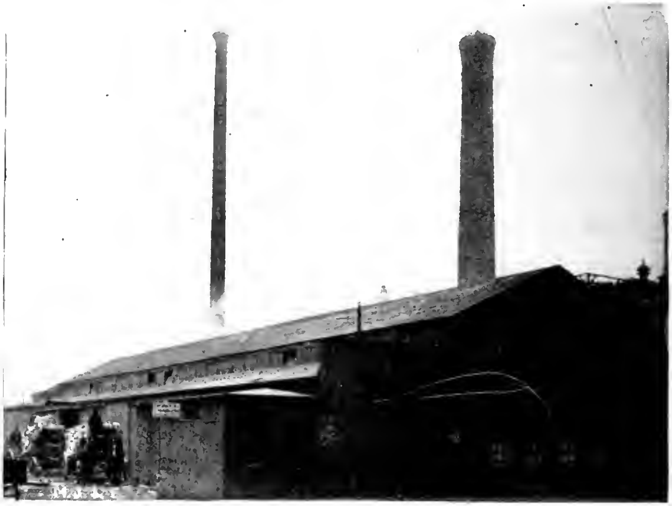

FIG. 19.—Refuse Utilization Station, Boston.

FIG. 20.—Refuse Utilization Station (receiving and sorting floor), Boston.

including the rejected matter from medical schools. They are installed in the basements of stores, and destroy what-

ever kind of waste is placed therein with entire efficiency, and with absolute sanitary results, and with economy in operation which mark them as a leading feature of the sanitary equipment of the establishments.

All this work in small furnaces has been accomplished within the last three years, and has been marked by the adoption of this one particular form of furnace.

The largest example of a destructor of this kind has been operating for some time in Manila, Philippine Islands, where, in 1902, a destructor of the *Morse-Boulger* type, with the capacity of 130 tons per day, was built. This destructor

FIG. 21.—Refuse Utilization Station (power and hand presses) Boston.

is supplied with forced draft furnished by the utilization of its own heat, and by this means it is able to operate with the consumption of the least amount of fuel required by any American furnace built for this purpose.

THE RECOVERY AND UTILIZATION OF WASTE SUBSTANCES.

In our examination of this subject one more form of construction appears, that which is adapted to the recovery and sale of such portions of refuse as are marketable, and the destruction of the remainder, valueless except for the production of heat. The methods instituted by Col. G. E.

Waring resulting from the experiments conducted by him have been found to-be practicable for the treatment of the rubbish of any northern town.

The 10 or 12 per cent. of waste, and the volume of rubbish which is annually produced comprise a great bulk of articles and substances which are valuable if they can be recovered in a condition reasonably free from dirt. The paper annually manufactured and used in the United States is sufficient to supply every inhabitant with 50 pounds of

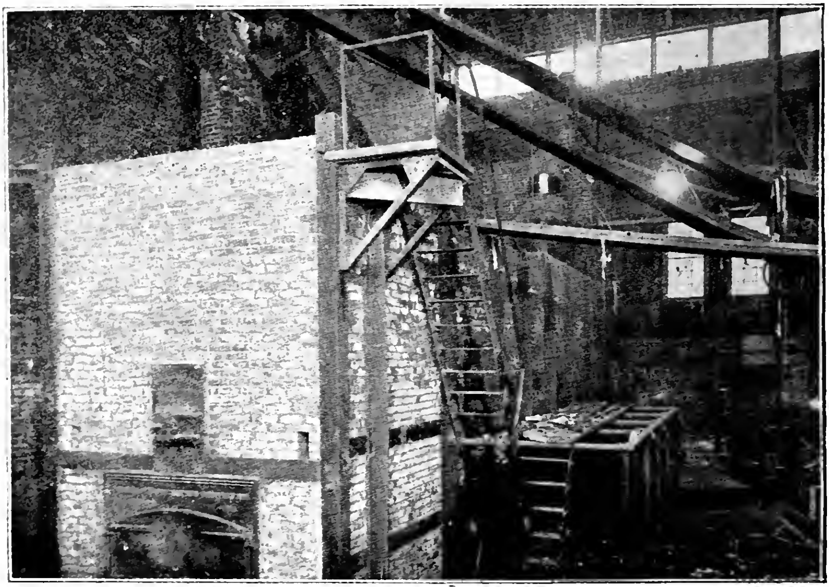

FIG. 22.—Refuse Utilization Station (the Morse-Boulger destructor, conveyer, boiler, engine, dynamo), Boston.

paper per year. In most northern cities the ratio of production of rubbish (which includes the paper rubbish, the most valuable part) is one ton of refuse daily to each 10,000 persons.

Colonel Waring introduced a system under which this paper was separately collected by city carts and brought to one central point in the collection district, and there spread upon a moving platform which passed between a line of

men stationed on either side, who recovered from the waste such parts as might be utilized or worked over into marketable articles. The worthless remainder was then carried by the moving belt down to the furnace, and the heat resulting from the combustion of this material was utilized for moving the machinery of the plant.

This method has been in use in Boston for five years at the Atlantic Avenue Refuse Utilization Station, where, within half a mile of the City Hall, from 25 to 30 tons per day of combustible refuse are sorted over and the worthless residuum consumed in the *Morse-Boulger Destructor* without offense. The heat is utilized and applied to the purposes of moving the machinery and of lighting and warming the entire plant.

THE APPLICATION OF THESE METHODS TO THE REQUIREMENTS OF PHILADELPHIA.

Application of the foregoing descriptions of disposal of waste by the method of cremation may be briefly made to the conditions in Philadelphia in the following manner:

In 1902 there was collected from the streets of the city an amount of waste consisting of garbage, ashes and street sweepings represented in round figures by 823,977 tons. Of this proportion about 280,000 tons represent the garbage disposed of by the reduction process. The amount paid by the city for this work was $490,000. This was an increase over the expenditures of 1901 of $50,000, and an increase of $43,000 over the expenditures of 1900. This shows, therefore, that the total cost of collection and disposal increased $93,000 in two years for garbage only.

The total payment for the collection and disposal of ashes and street sweepings was $720,890. In one year this increased $125,000, and in two years $65,000 more, making a total increase of $191,000 in three years for ashes and refuse.

The refuse collection in 1901 amounted to 15,000 loads. In 1902 it was practically the same; but in 1903 it was 30,000 loads, an increase of 15,000 loads in three years.

The total amount of the bulk of the city waste was 823,977 tons. If the methods employed in England were

FIG. 23.—A Philadelphia refuse dump.

FIG. 24.—The recovered material at a Philadelphia refuse dump.

applied to the destruction of the waste of Philadelphia, it would be done by the erection in four quarters of the city of large plants completely equipped and supplied with furnaces of large capacity, furnished with steam boilers developing steam power by the combustion of the mixed municipal waste. As one pound of water is evaporated for every pound of waste, this would develop 10,000 horse-power daily for 365 days in the year. But as the conditions may vary somewhat from those of the English cities, it would be fair to assume that one-half of this quantity of water would be evaporated, giving a daily horse-power of 5,026. The value of this horse-power calculated in electrical units would be 157,800 British Board of Trade units. The average candle-power of this steam would be equal to 152,960 incandescent lamps of 8-candle power.

Our conditions may be somewhat different from those of the British towns; but the fact remains that the city of Philadelphia can destroy its 900,000 tons of municipal waste by cremation in a satisfactory, entirely sanitary manner, and can develop power thereby, which, when applied to electric lighting, will serve to illuminate a very large area, certainly one-third of the city. These calculations are proved by the practice of the English cities, where in sixty-three cases the power obtained from the combustion of the city waste is applied as auxiliary to the electric lighting stations.

The last consideration, and one of the most practical moment in Philadelphia, is the disposition of the rubbish, which, as has been shown by the work done in Boston, is a matter of great present importance. Take the 30,000 loads that were collected last year by the street-cleaning department, taken to the various city dumps, and there disposed of in a very unsanitary and extravagant way; suppose that instead of being distributed broadcast over the dumps these loads were taken to three stations, the city being divided into three districts, and the loads delivered direct to the stations by the contractors, or by the city teams. There would be erected three refuse utilization stations similar to those now in operation in Boston and in New York, each of which would have 10,000 loads to dispose of yearly. If we

reckon the saving to be had, as shown by the work in Boston and New York City, we may say one-half of this waste may be turned into money by the agency of the various stations erected by the municipality. This amount would be represented by $40,000 per year, derived from the sale of the marketable portions of the waste. There would also be the surplus steam power obtained from the destruction of the worthless parts of this refuse, which could be transformed into electric power, or put to some other use, or conveyed and sold to manufacturers.

The work in Boston shows that after five years' service the steam power produced by the destruction of the worthless portions of refuse is more than sufficient to do the work required by the machinery of the station. This seems to be the practical idea of the destruction of waste matter as applied to the conditions of the city of Philadelphia. Suppose that the city were to build three stations of this character; suppose that, as in New York, the city should invest money in these plants, say, roughly speaking, $125,000, that these plants were operated by contract, the revenue to the city would be at the rate of $1.00 per ton, the expenses of the plant would be defrayed, and there would be left sufficient margin to reimburse the contractor for operating the station. In other words, the city would by its own action bring into use an agency for the abolition of the objections made to the dumps, would be repaid for its outlay, and in three or four years have three completely equipped refuse disposal stations for future service that would return a revenue in increasing measure every year.

The Street-cleaning Commissioner in New York reports that from one station of this kind, where the average daily receipts are 30 tons, the return in money to the city is about $250 per week in cash, and an equivalent amount in the saving of transportation expenses. This is sufficient proof that the work is not only sanitary and practical, but that it is also one in which the city can engage with absolute certainty of protecting itself against financial loss.

This method of dealing with refuse has already attracted the attention of other cities besides Boston. New York is

about to construct a second disposal station; St. Louis will follow with two stations; and Buffalo has now under contract the building of one large central station, at which the steam power developed by the combustion of the worthless parts of refuse will be utilized to pump the sewage from a large area of the city.

In conclusion, waste disposal methods in the United States are at present in a transition stage. Thus far the experiments of individual inventors or municipalities in the construction and operation of disposal plants have not been altogether satisfactory. With but limited success large amounts of money and years of time have been spent in efforts to obtain lucrative and sanitary reduction processes, or odorless, economical and durable crematories. Although reduction methods have been adopted by contract with private parties in several cities, their general adoption is likely to be very slow, as they require a large sum for establishment, and there is no certainty of their continuance except by means that constitute a practical monopoly.

Thorough examination of the requirements of a city by technically skilled men, and the unbiased and carefully considered recommendations of approved methods by competent engineers to the city authorities would give the whole subject the standing and character which it now lacks. The disposal of waste should be considered as much a part of necessary municipal work as any other department of the city government, and it should be approached with the respect and consideration that the magnitude of the financial interests and the laws of sanitation involved may demand.

Under these conditions progress can be secured and upheld. By the power of these agencies working together for a common purpose, the elimination of worthless and dangerous matter in a safe and economical way can be established and maintained, and the proper methods become important factors for the preservation of the comfort and health of American communities.

Mechanical and Engineering Section.

Stated Meeting, held Thursday, October 22, 1903.

Modern Expanding and Flanging Machinery and Tools.

By Luther D. Lovekin,
Chief Engineer, New York Shipbuilding Company, Camden, N. J.

(*Concluded from vol. clvii, p. 435.*)

TOOLS FOR CLASS "A" SIZE MACHINE.

The above-mentioned tools consist of a steel casting shank and body, in one piece, bored out to receive a forged steel mandrel, as shown in *Fig. 4*, and the body is slotted out to suit the feeding screw *F*, in order to give the inner mandrel *E* the proper movement necessary for expanding. The feeding screw *F* engages into the feeding wheel *G*, and, as will be seen, any movement of wheel *G* causes the feed screw *F* to move outward or inward as desired. Feeding wheel *G* is held in place by a nut at the rear end; this nut also takes the thrust due to forcing the expanding and flaring rollers ahead, and is also provided with a facing at the rear end, which when unscrewing from the mandrel proper, comes in contact with the socket head on machine, and thus makes a very useful device for withdrawing the tool shank. The shank is provided with suitable feather and set screw for holding tool in place, and the end of shank comes in contact with the bottom of the bore in socket, thus giving a very firm backing for the tool proper, in case of excessive end thrust.

As will be seen, the shank is arranged at its front end to receive a series of detachable heads to suit the various sizes of pipes. These heads are made of steel castings suitably bored for the end of the shank on body of tool, and are also provided with suitable key-way and feather in addition to the set screw as shown. Each head has a series of slots, suitably finished to receive the expanding and flaring rollers, and the said rollers are held in place by means of set screws, as shown. All faces on the heads com-

ing in contact with rollers are hardened to insure lasting qualities.

The central rollers are mounted freely on the reduced portion of mandrel *E*, and are provided with suitable anti-friction washers at their rear end to absorb the thrust. These rollers are of tool steel, hardened, and are held in place by suitable nut and washer at the end of the mandrel, as shown.

The principle embodied in this expander is that of a central revolving roller, upon which operate the expanding

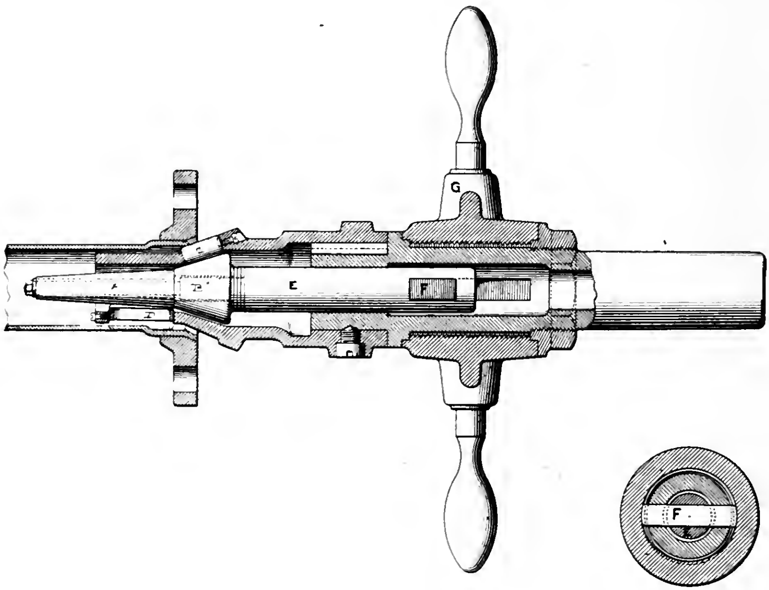

FIG. 4.—Showing principle of construction of the tools.

rollers; the mandrel having no work to perform further than forcing the central rollers outward and inward, as desired, they are therefore not subjected to the immense torsional stresses of other types, which constantly require new mandrels. These central rollers have no bearing on the mandrel whatever.

It will be readily seen from the description given that the operation of expanding is very simple; thus, after the tool is in position in the machine and the pipe and flange set cen-

tral with the spindle, all that is required is to start the motor on the machine which revolves the tool. The expanding is done by simply holding the feeding wheel fast, as this advances the inner mandrel, which causes the rollers to expand. Turning this feeding wheel in the reverse direction causes the rollers to collapse. The expanding tool will be found desirable when setting the pipe central; thus, in order to insure the "V" grips being properly adjusted, it is well to advance the tool inside the pipe and expand out enough to hold the pipe central, then examine the "V" grips and the jaws to see if the bottom of the grooves are at least $\frac{1}{8}$ of an inch clear at the side of the flange; then adjust the "V"

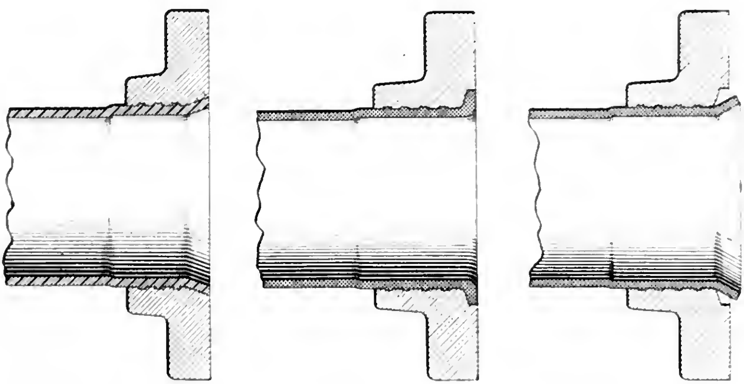

FIG. 5. FIG. 6. FIG. 6a.

grips to come in contact with the pipe (while this side clearance is maintaind in the jaws, clamp "V" grips solid to jaw); release the expander and grip the pipe firmly by turning the hand wheel provided for such. This operation is only necessary when setting the first piece of pipe, in order to avoid any mistake, as when once set for a certain size flange and pipe, all others of the same size can be set completely ready for expanding in about two minutes' time.

Fig. 5 shows a sample of bilge and ballast piping for vessels. This same joint is used for oil mains throughout the country, and will also pass the United States inspectors' rules for steam piping.

Fig. 6 shows the most recent method of rolling copper

and steel piping in flanges, for both United States Navy and the Board of Supervising Inspectors of Steamboats in the United States.

Fig. 6a shows the amount of work done by the expanding and flaring tools in all copper pipe work, thus leaving the coppersmith to finish the joint, as shown in *Fig. 6*, by simply hammering the ends down into the recess. This is done so as to avoid the necessity of having too many different-shaped tools on hand, the work of finishing up such a joint requiring but a few minutes to perform. It is well known that the expanding takes up at least 90 per

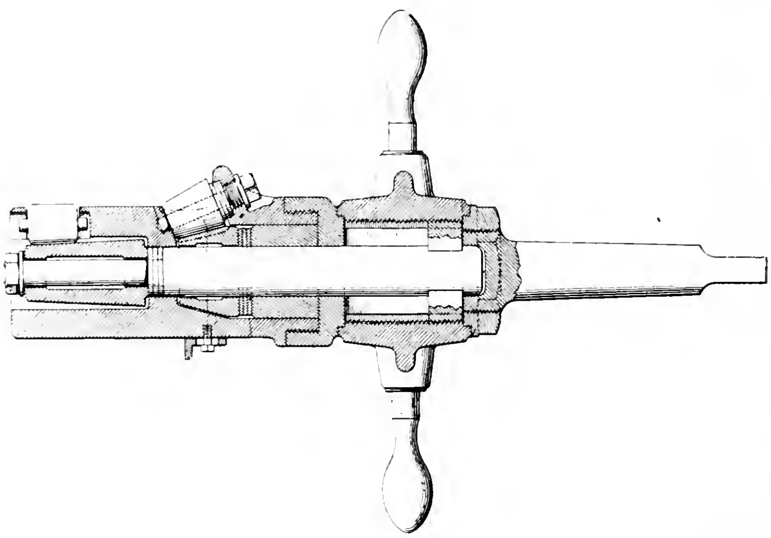

FIG. 7.—Lovekin patent expanding and flaring tool with cutter for all piping.

cent. of the total time necessary to complete a joint, the flaring takes fully 5 per cent. of the total time, thus it leaves but about 5 per cent. of the total time to hammer over after the flaring is done. If, however, the complete joint is required, suitable tools are furnished for doing both iron and steel or copper complete, as shown in *Fig. 6*. These tools are also provided with cutters to face off the ends of pipe after it is expanded into the flange if desired.

In addition to these new machines and tools for doing

copper, iron or steel pipe work, we have designed several other machines and tools (*Figs. 7* to *12*) for doing all classes of work, which may be mentioned as follows:

Class "A" machine, for doing iron, steel or copper pipe, from 2 inches to 7½ inches, inclusive.

Class "B" machine, for doing iron, steel or copper pipe, from 8 inches to 16 inches, inclusive.

Class "C" machine, for wrought iron or steel pipe, 16 inches to 24 inches, inclusive.

This latter machine, for wrought iron or steel pipe, has hydraulic forcing attachments for placing the flanges on

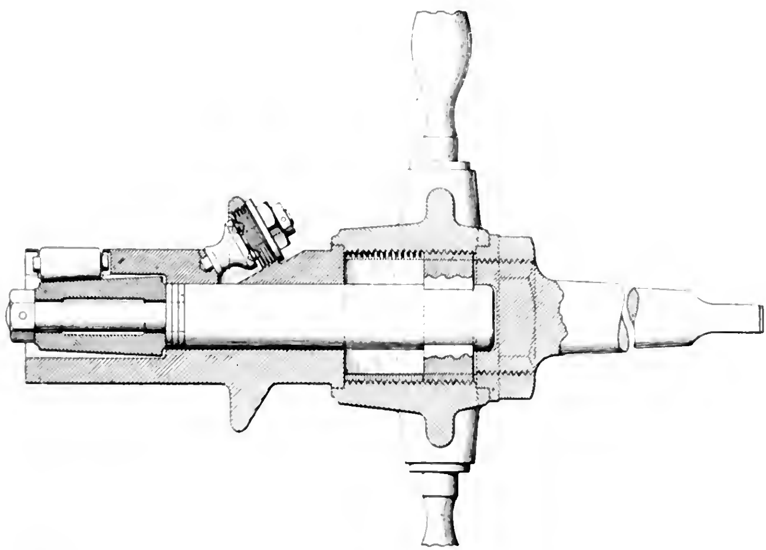

FIG. 8.—Lovekin patent expanding and beading tool for copper pipe only.

pipe prior to expanding, and is also provided with suitable davits on the sides of machine for lifting flanges and tools in place. This machine I believe to be the largest of its kind ever built in the world, and will handle pipe 20 feet long, 24 inches in diameter. The tool itself will weigh 2,200 pounds and the machine will weigh approximately 15 tons.

We have also designed, built and tested:

Boiler tube expanders, as shown, in sizes from 2 inches up to 8 inches. These tools are based on new principles,

and can be used in a pneumatic motor of any of the popular makes, as well as by hand if desired, with less wear than the ordinary boiler tube expander, and with no possibility of breakage of any part. The rollers will outlast all others in use, and the mandrel never wears out, having practically no work to perform. The roller on mandrel will outlast the ordinary expanders, inasmuch as all torsional

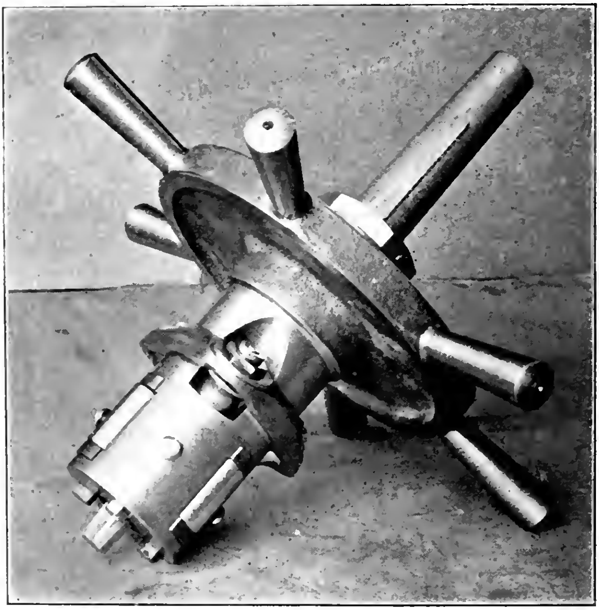

FIG 9.—Lovekin patent expander and beader for light metal tubes.

strains are removed, and the usual cutting away of the mandrel is not noticed.

In addition, the flaring tools deserve special attention, inasmuch as they are an entirely new product, based on experience, and I believe them to be the best tools ever made for doing such work, with no possible injury to the pipe or tube, such as cracking or splitting at the ends. These tools can be used after expanding the tube, and previous to beading over, in place of hammering, as is usually done. They will save much time and labor and do the work perfectly,

something that cannot be said of the hammering process where tubes are cracked time and again.

VALVE-SEAT EXPANDERS.

These tools are made to work in conjunction with turret lathes, the tool being held fast and the valve revolved on the face plate. The seat is placed in the valve (as shown in *Fig. 11*), and the tool is then forced up until it reaches the face of the seat; this being done, all that is necessary now is to hold the hand wheel which feeds the mandrel

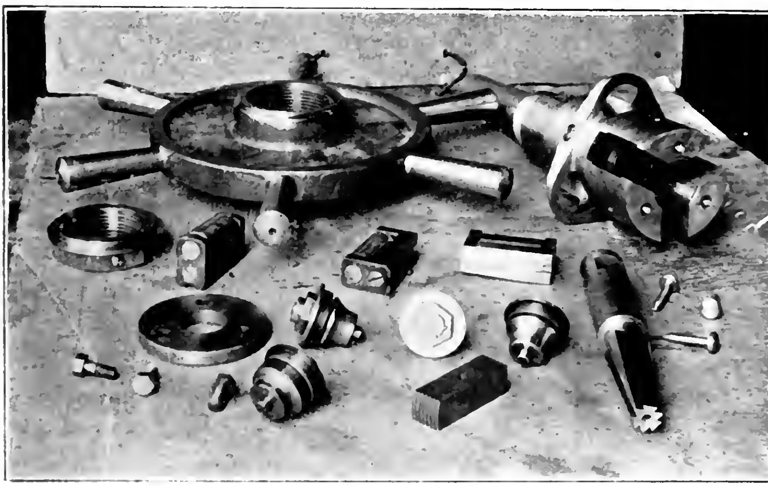

FIG. 10.—Details of Lovekin expander and beader for light metal tubes.

forward, and the small rollers outward, until fully expanded. I believe this method to be far better than screwing seats in valves, and will be found a great help to the makers of large gate valves, as well as other valves.

I made some tests on 2½-inch boiler tubes, samples of which are on the table for inspection with no sign of leakage under 2,700 pounds pressure per square inch, the pipe itself stretched $\frac{1}{32}$ in 9 inches, and I was unable to pull the pipe apart on account of the pressure not being sufficient. I might state that on most tests with ordinary expanders leakage occurs with 1,200 to 2,000 pounds pressure. I believe

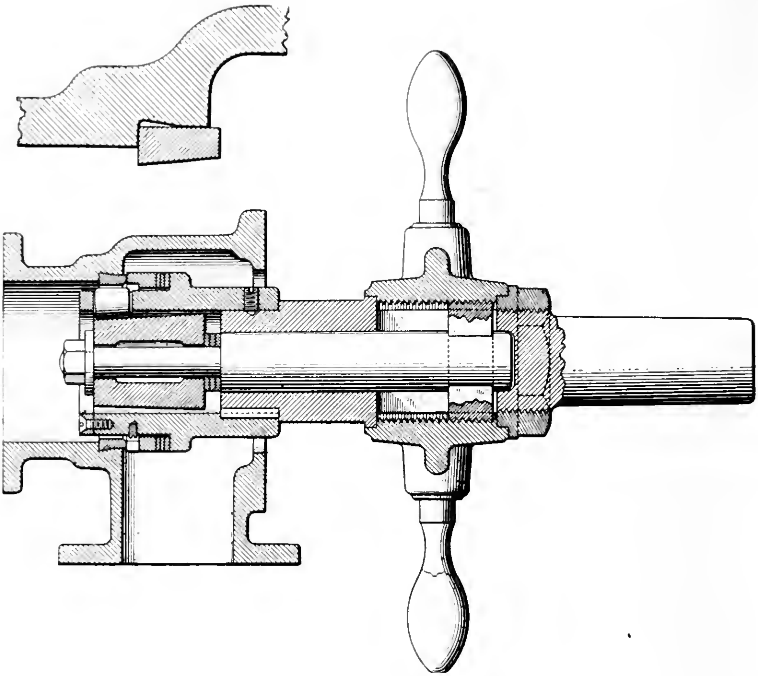

FIG. 11.—Lovekin patent valve seat expander.

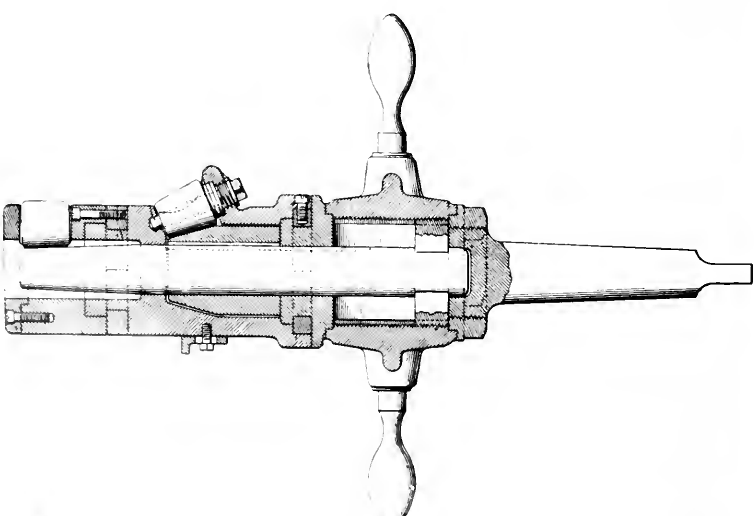

FIG. 12.—Lovekin patent internal driven expander and flarer with cutter.

the joint, as shown by me, would make an excellent boiler tube joint, inasmuch as every tube would become a stay tube.

MEMORANDUM OF PROPER SPEEDS FOR EXPANDING BOILER TUBES; ALSO, COPPER, IRON AND STEEL PIPING.

After experimenting for several years the following speeds are suggested as being the best possible, in order to

FIG. 13.—Lovekin patent-boiler-tube or flue expander.

insure good, tight work and prevent flaking or scaling of the metal in tubes:

	Max. Speed. Revolutions.	Best Speed. Revolutions.
2-inch Boiler Tube	40	30
2½-inch " "	35	25
3-inch " "	30	20
3½-inch " "	25	17½
4-inch " "	20	15

For other tubes calculate the speed of the tool so as to run at about 15 feet per minute—do not exceed 20 feet. Thus, assuming 8 inches diameter of tube, the circumference is approximately 24 inches or 2 feet, so that we would require to run about $7\frac{1}{2}$ revolutions per minute.

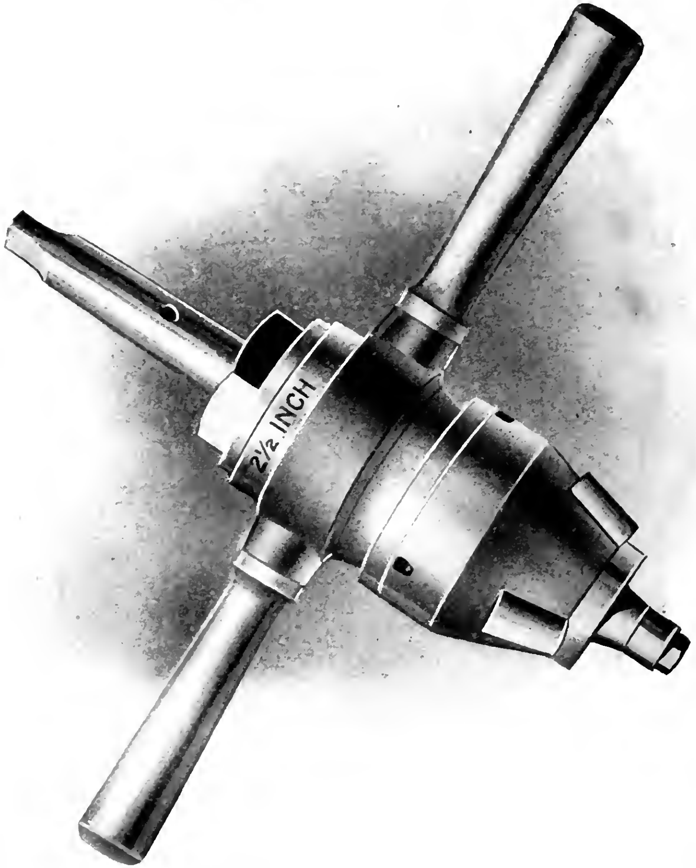

FIG. 14.—Lovekin patent boiler tube flaring or beveling tool.

The following is a description of the boiler tube expanding and flaring tools: These tools can be used in connection with a pneumatic motor of any of the popular makes, and by simply pressing the expander against the tube plate and starting the motor, the expander revolves, the feeding is done by simply holding the handle, while the tool is revolving.

This causes the inner mandrel to come forward, which forces the tapered roller between three or more outwardly expanding rollers. After the tube has been expanded, in order to withdraw same, the handle is turned in the reverse direction, which causes the rollers to collapse (*Figs. 13* and *14*).

The great advantage derived from an expander of this kind is the avoidance of any hammering upon the tapered pin, or any other part of the tool, and the avoidance of any difficulty in expanding or forcing the rollers over lumpy welds. Another important point is that of applying the power at the outside instead of at the taper pin; this facilitates rolling imperfect interior tube surfaces, such as lumps or rough welds, and eliminates the jerking motion so prevalent in the old-style expanders, where lumps are found in the tubes. The rollers are made with proper taper to bring the surface of the rolls parallel with the interior of the tube, thus insuring a good joint throughout the entire tube sheet. The flaring tools are made on the same principle, for doing all classes of flared work (such as the Hartford Boiler Insurance Company require), and I can guarantee these tools to do the work without splitting the tube at the ends. This is also an excellent tool for boiler-makers to use after expanding the tube, as it does away with all hammering, and completes the tube ready for beading over with boot-heel tool.

The scope of these expanders can be greater than with any other form, and the diameter of the tube can be any size desired from 2 inches to 24 inches, without changing the principles of expanding. This is not possible with any other class of expanding tool yet offered.

It might be well to state that instead of using the handle for feeding the central roller, a ratchet or spanner may be employed, when desired, for working in close quarters, and the tools can also be worked by hand, similar to the old-style expander, if desired.

CONCLUSION.

At a later date I made up samples of iron, steel and copper piping as shown, and had these tested to destruction in

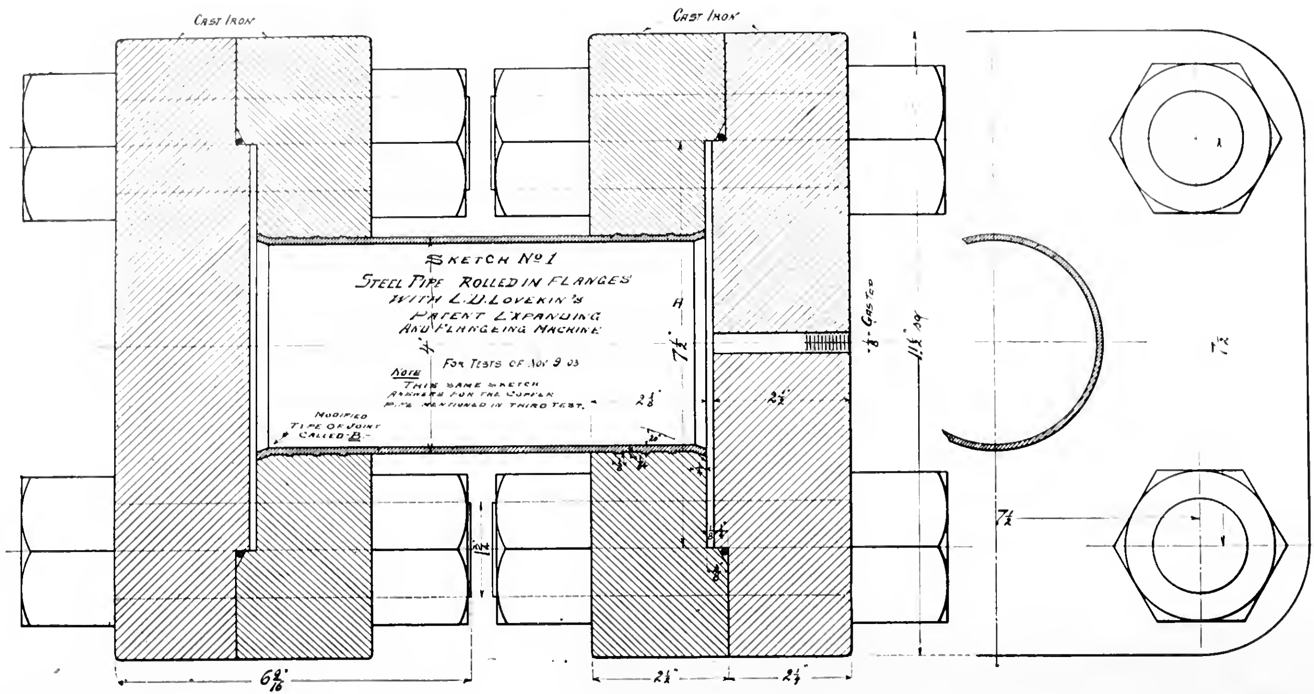
Cast Iron
Cast Iron
Sketch No 1
Steel Pipe Rolled in Flanges
with L. D. Lovekin's
Patent Expanding
and Flangeing Machine
For Tests of Nov 9 03
Note
This same sketch
answers for the copper
pipe mentioned in third test.
Modified
Type of Joint
Called B
6 9/16"
2 1/4"
2 1/4"
7 1/2"
11 1/2" sq
7 1/2
4"
2 1/8"
1 1/4
1/8 Gasted

FIG. 15.

nearly all cases to see the effect of pulling flanges off the pipe.

These tests were made at the laboratory of The Quimby Engineering Company, 915 Ridge Avenue, Philadelphia, Pa., whose report follows:

NOVEMBER 11, 1903.

Mr. L. D. Lovekin.

DEAR SIR:—The following is my report on tests of expanded and brazed pipe joints:

On November 9th I started the test on a piece of 4-inch, inside diameter, steel tube No. 10, B.W.G. thick, expanded into cast-iron flanges on each end $2\frac{1}{2}$ inches thick, each end being covered with cast-iron blank flanges $2\frac{1}{2}$ inches, these being held by four $1\frac{3}{4}$-inch bolts, a standard $\frac{1}{8}$ inch gas pipe connection being tapped into one end for applying hydraulic pressure, all being the same as per drawing M, — 1 and M, 2. (*Figs. 15* and *16.*)

On applying pressure up to 2,500 pounds per square inch, a slight weeping was noticed in one of the expanded joints. Below 2,500 it was perfectly tight. This did not seem to increase materially as the pressure increased. On this test we had great trouble with the round rubber used for making the joints. It was of poor quality and blew out. After repeated trials we managed to get 3,200 pounds per square inch with an elongation of about $\frac{1}{32}$ of an inch without any permanent set, showing the elastic limit had not been reached. A second test was made on this specimen after getting new rubber, and a maximum pressure of 3,800 pounds per square inch was attained without any set in the pipe. At this pressure the flanges sprung apart, allowing the packing to break. This occurred on several trials at about the same pressure, showing that the flanged joint would have to be strengthened with additional bolts or clamps for a higher pressure test.

The second test was made on a piece of 4-inch, inside diameter, copper pipe, $\frac{5}{32}$ of an inch thick, each end being hammered and brazed into composition flanges $1\frac{3}{8}$ inches thick, otherwise being the same as test No. 1. *Figs. 17* and *18* show, respectively, the shape, etc., of the specimen

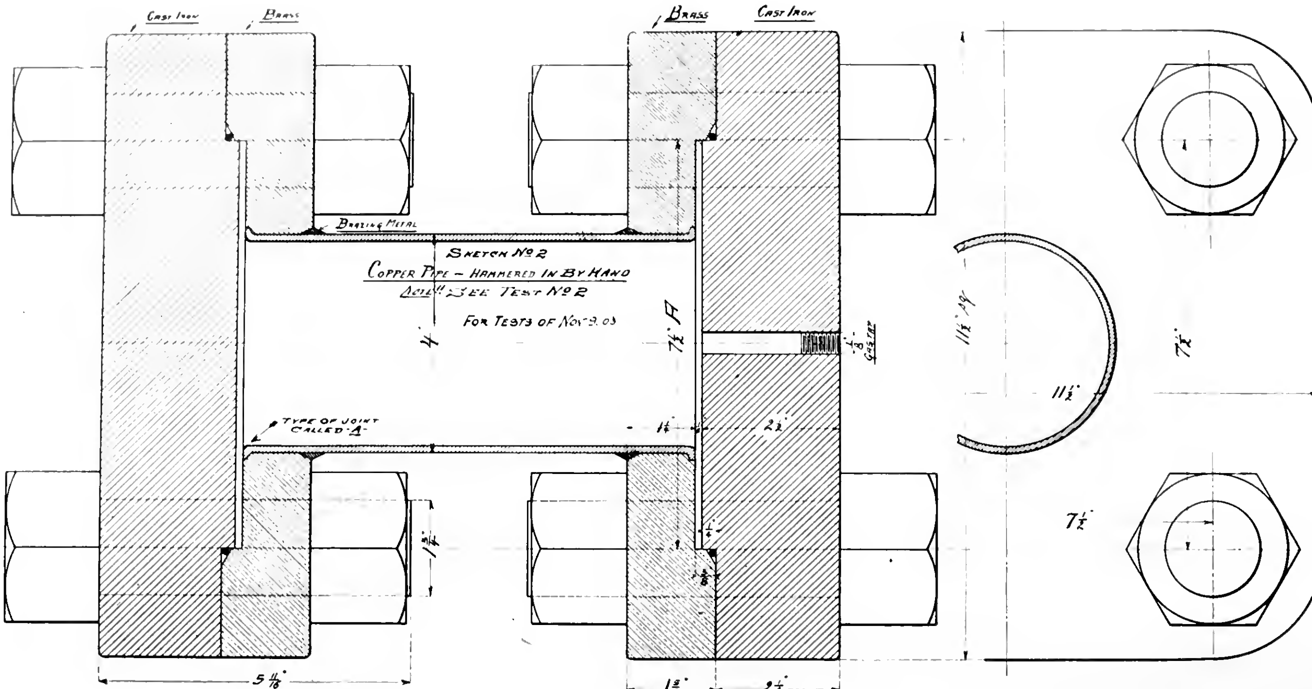
Cast Iron
Brass
Brass
Cast Iron
Brazing Metal
Sketch No 2
Copper Pipe – Hammered In By Hand
Add'l See Test No 2
For Tests of Nov 9.03
Type of Joint Called "A"
5 1/16"
1 5/8"
2 1/4"
1 3/4"
7 1/2"
11 1/2"
4"

FIG. 16.

before and after the test. This pipe began to elongate at 600 pounds per square inch, with a permanent set of $\frac{1}{32}$ of an inch at 800 pounds per square inch from this pressure until 1,900 pounds per square inch was reached, when the pipe

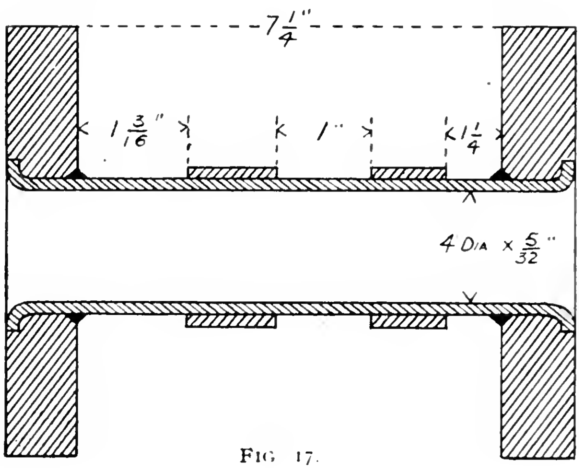

FIG. 17.

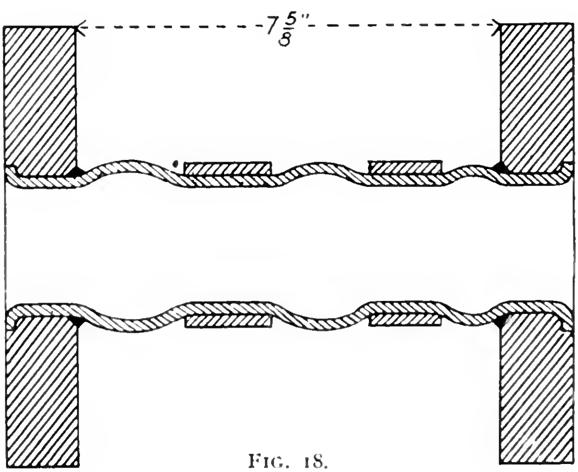

FIG. 18.

burst near one flange, as indicated on *Fig. 18*, at the brazing. The elongation was $\frac{3}{8}$ of an inch, the pipe also bulged considerably in the center from $4\frac{1}{4}$ inches to $4\frac{3}{8}$ inches, and near flanges to $4\frac{7}{16}$ inches in diameter. There is every rea-

son to believe that if the pipe had not burst as it did, that with a small increase in pressure the pipe would have pulled apart. The brazed joint, as far as I could see, was intact.

The third test was made on a piece of 4-inch, inside diameter, copper pipe, $\frac{5}{32}$ of an inch thick, each end expanded into cast-iron flanges $2\frac{1}{2}$ inches thick by your method, otherwise being the same as test No. 1.

At 3,000 pounds per square inch,	elongation was $\frac{1}{32}$ of an inch, no permanent set in length of tube.
" 3,500 " " " "	elongation was $\frac{1}{16}$ of an inch with a permanent set in length of tube.
" 3,800 " " " "	commenced to pull flange off of tube very slow.
" 3,400 " " " "	flange slipped on tube $\frac{5}{16}$ of an inch with a jump.
" 600 " " " "	flange slipped on tube $\frac{5}{32}$ of an inch, pressure dropped to 400 pounds per square inch and, gradually getting less, pushed the flange completely off the tube.

It was noticeable that after the joint slipped $\frac{5}{16}$ of an inch and applying the pressure a second time, there was absolutely no leak.

There were three grooves in the bore of the flanges, $\frac{1}{8}$ of an inch wide by about $\frac{1}{64}$ of an inch deep. These grooves were filled with the copper and sheared off during the 3,800-pound test, but the flaring at the ends was compressed into the hole in the flange and drawn through. The flange on the other end showed that it had also started. The expanding was perfect, as the copper tube shows every tool mark in the boring of the flange; it also shows that the metal had flowed well into the grooves.

The difference between the strength of the pipe brazed and the one not brazed is particularly noticeable, viz:

Using the U. S. Navy formulæ for copper pipe

$$T = \frac{P \times D}{8000} + \frac{1}{16}$$

and solving for P on the above thickness of pipe, viz., $\frac{5}{32}$ of an inch, we have

$$\frac{\frac{3}{32}'' \times 8000}{4''} = 187 \text{ pounds}$$

per square inch working pressure that 4-inch I. D. ⁄ $\frac{5}{32}$ of an inch copper pipe is good for.

In the case of the brazed pipe we have

$$\frac{800 \text{ pounds elastic limit}}{187 \text{ pounds working pressure}} =$$

about $4\frac{1}{4}$ as the factor of safety up to the elastic limit.

In the case of the expanded pipe we have

$$\frac{3{,}500 \text{ pounds elastic limit}}{187 \text{ pounds working pressure}} =$$

about 18·7 as the factor of safety up to the elastic limit. This shows that the strength of the brazed pipe was lowered 4·4 times below the strength of the expanded joint not annealed.

The total load required to start the flange on the tube was:

A = area outside diameter tube.

P 9 = pressure per square inch on the above area when joint started to slip.

3,800 pounds × 14·6 square inches = 55,480 pounds pull.

$\frac{55{,}480}{2}$ = 27,740 pounds stress per square inch.

Area — $4\frac{5}{16}$ of an inch = 14·6.

" — 4 inches = $\frac{12·56}{2·04}$ square inches, say, 2 square inches of metal.

The copper was good for about 30,000 ultimate tensile strength.

The pressure used on these tests was hydraulic applied by a screw press, so that the pressure was applied gradually and there was no possibility of sudden shocks or pressures such as would come from a plunger pump. The pressures were read from a Shaw Differential-Plunger Mercury Gage, U. S. Standard, the accuracy of which is well known.

There were forged steel bands applied to each pipe on test, as shown in *Figs. 17* and *18*, to prevent the pipes from bulging and bursting under the excessive pressures required

to pull them apart. These bands were $\frac{3}{8}$ of an inch thick by about $1\frac{3}{4}$ inches wide.

(Signed) QUIMBY ENGINEERING COMPANY,
per W. S. QUIMBY.

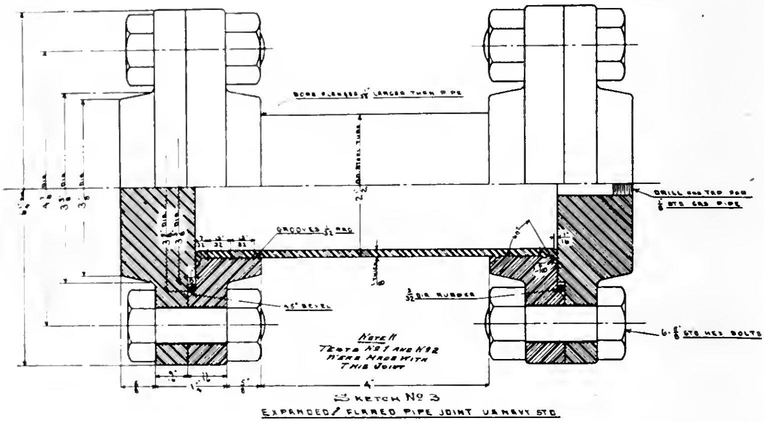

FIG. 19.

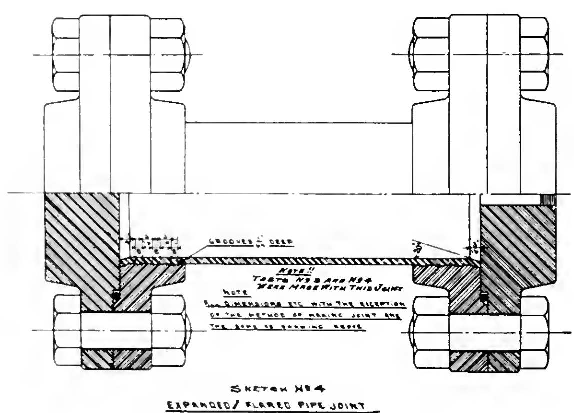

FIG. 20.

I also made several tests on November 18, 1903, at the Quimby Engineering Laboratory, on $2\frac{1}{2}$-inch steel tubing, as made by the Shelby Tube Company, with standard U. S. Navy forged steel flanges, as shown in *Figs. 19* and *20.* These tests were made with a view of ascertaining the

value of a joint, as proposed by me, compared with a joint made in accordance with the U. S. Navy method of rolling the metal over into a recess, as shown. Both of these pipes were rolled into flanges with my expanders, so as to get a fair comparison, the results of which are appended.

According to the reports of the Quimby Engineering Company, all previous tests of tubes rolled into plates have failed under a test pressure of 1,200 to 2,000 pounds. And I can say with certainty that with my tools we can obtain test pressures of fully double that of an ordinary expander.

PHILADELPHIA, November 23, 1893.

Mr. L. D. Lovekin :

The following is the report on tests of expanded pipe joints, made with specimens as per drawing:

Test No. 1.—The tube being expanded into flange by your patent tube expander, was afterward carefully beaded by hand, conforming to the U. S. Navy Standard Rules. Pressure was applied gradually, when pipe began to stretch at 2,600 pounds, and a slight weeping at joint was detected when pressure had reached 4,200 pounds; pressure was then reduced and rubber gasket was renewed.

Pressure was again applied when at 4,650 pounds, pipe stretched $\frac{1}{64}$ inches, showing that it had reached its elastic limit, when one bolt in flange broke. No leak had occurred in joint up until breakage of bolt. After the renewal of same, bolts began to stretch at 5,200 pounds pressure, when a slight weeping again occurred, but joint withstood a pressure of 5,600 pounds, when gasket blew out.

Summary.—During this test, pipe attained a permanent stretch of $\frac{1}{32}$ inches with a lateral bulge at center of $\frac{3}{64}$ inches.

(Signed) QUIMBY ENGINEERING COMPANY,
per W. S. QUIMBY.

PHILADELPHIA, November 23, 1903.

Mr. L. D. Lovekin :

Report of Test No. 2.—Pipe was expanded into flange by your patent tube expander, and beaded by hand, conforming with the U. S. Navy Standard Rules, 1,000 pounds pressure

being applied at start, then the pressure was increased by stages of 200 pounds until reaching 5,000 pounds rubber gasket blew out. After renewal of which pressure was again applied, until upon reaching 5,900 pounds bolts gave out, clearly showing that pressure had been applied beyond bolt section, and that bolts were not sufficiently strong to withstand the test.

Pipe bulged $\frac{1}{16}$ inch at center during test.

(Signed) QUIMBY ENGINEERING COMPANY,
per W. S. QUIMBY.

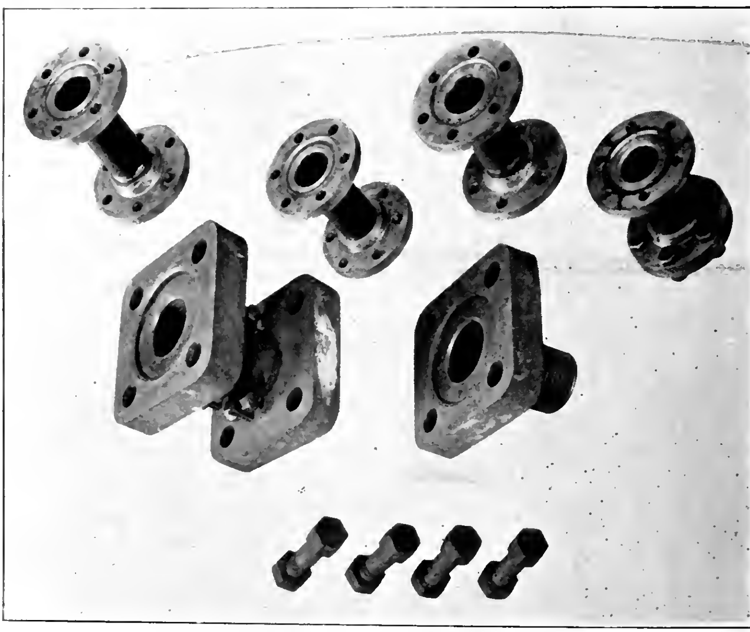

FIG. 21.—Test specimens.

PHILADELPHIA, November 23, 1903.

Mr. L. D. Lovekin:

Tests Nos. 3 and 4 respectively.—Joint was expanded only, and by your method, no beading having been resorted to.

Pressure at start was 1,000 pounds; this was increased by 1,000 pounds increments. Upon reaching 4,900 pounds pipe pulled out of flange nearly $\frac{1}{4}$ inch; pipe also bulged $\frac{1}{32}$ inch at center.

Test No. 4.—Same condition prevailing with regard to joint, as in the preceding test.

A starting pressure of 1000 pounds was applied, and then increased to 2,000 pounds, 2,500 pounds, 3,000 pounds, 3,800 pounds, 4,000 pounds, and then by stages of 200 pounds until having reached a pressure of 5,900 pounds, flange pulled nearly off from pipe, while the pipe bulged $\frac{1}{16}$-inch at center.

The same factor of safety applies to both tests, Nos. 1 and 4, as the pressure applied and attained was the same in both cases.

(Signed) QUIMBY ENGINEERING COMPANY,
per W. S. QUIMBY.

Fig. 21 shows a photograph of several test pieces as exhibited at the meeting.

IMPROVEMENT IN YARN MANUFACTURE.

An invention has recently been made by an English manufacturer which relates to improvements in yarns such as are to be used in the manufacture of textile goods, the object being to construct a serviceable yarn from material which has hitherto been considered of little or no value, or to construct an exceptionally strong yarn at a very cheap rate. The invention consists of a yarn having a core or center thread around or upon which is the body or yarn proper. The core yarn may consist of one or more materials, such as cotton or worsted, or a combination of the two, and the body of cotton or other material, such as silk, wool, shoddy, mungo, flax, waste, or a combination of any of these. According to this invention, the core thread (consisting, say, of cotton) is covered entirely with any other desired fiber (say, of wool), so combining the strength of the core with the utility or appearance of the body. By combining the core and body as described, fibers, such as waste or mungo of such short staple as to be of practically no spinning value, may be utilized in the manufacture of textile goods possessing equal or greater strength and being similar in appearance to goods manufactured from high class fiber. The core and body constituting the improved yarn are combined in the following manner:

The fiber forming the body of the yarn is removed from the swift, or carder, by means of a condenser doffer and card and iron strippers in the ordinary way, and the core thread is brought from any adjacent point to and between the card stripper and the iron stripper, from which point the two together pass between the rubbers and the body is rubbed around the core sufficiently to keep the two together when on the condenser bobbin, from which the yarn is spun in the ordinary manner.—*Scientific American Supplement.*

RADIUM IN MINERAL WATERS.

As bearing on the distribution of radium in nature, some results obtained by R. J. Strutt and given by him in a paper read before the Royal Society, March 10, 1904, are of interest. Mr. Strutt found that deposits from two hot springs at Bath and one at Buxton, England, showed radio-activity. The rate of decay of emanation from the deposits was found to be identical with that of the emanation from radium, and there is every reason to believe in the presence of radium. The quantity present of this element is, however, very small, the total amount contained in the water discharged by the Bath spring during a year being estimated at 1/5 of a gram. The spring gives off about 100 cubic feet of gas per day, about 0·1 per cent. of which is helium, so that about 1,000 liters of helium are given off annually. The proportion of helium to radium, though somewhat larger than in the radio-active minerals, is in accordance with the view that the spring draws its supply from the disintegration of such minerals.—*Engineering and Mining Journal.*

EFFICIENCY OF MODERN DISTILLING APPARATUS.

The combustion of 1 pound of coal in a well-designed boiler furnace will evaporate from 8 to 10 pounds of water, which is considered a fair commercial rating. But in the purification of bad water or sea water by distillation the fuel cost of the direct process is practically prohibitive. By using distillers built on the so-called Yaryan multiple-effect system it is possible and practicable, however, to more than quadruple the evaporative power of a pound of coal, or rather to more than quadruple the product of distilled water. The steam from the main boiler is led into what to all purposes is another boiler, and by its condensation it evaporates the water containing impurities, the steam from which passes into another so-called boiler and repeats the operation. The result is that each drum acts both as an evaporator and as a condenser. The successive evaporations are made possible by maintaining a successively decreased pressure in each boiler. A Scottish firm, Mirrlees, Watson & Co., Glasgow, recently built two sextuple-effect distillers for the Egyptian Government which yield about 45 pounds of distilled water for each pound of coal. Each plant consists of six horizontal cylinders arranged vertically, one over the other, the total height being something like 39 feet. The pressure in each shell is graduated, being less in each successive effect than in the preceding one, which makes it possible to boil the water in one by absorbing the heat of the steam in the preceding effect. The apparatus, of course, includes steam pumps for maintaining the circulation.—*Machinery.*

CRYOSTASE.

A curiosity of the physico-chemical domain is cryostase, a mixture of equal parts of phenol, saponin, camphor, and a little turpentine oil. This body possesses the astonishing property of liquefying in cooling and solidifying on being heated. True, albuminoids also have this peculiarity, but in distinction from these, the process can be repeated any number of times with cryostase. Solidified albumen cannot be liquefied again by means of cold.—*Deutsche Medizin Zeitung.*

Mechanical and Engineering Section.

Stated Meeting, held Thursday, March 24, 1904.

The Execution of Architectural Design.

BY JOHN MCARTHUR HARRIS, M.A.,
Member of the American Institute of Architects.

When your Secretary asked me to speak to you I told him I would take for my subject "The Execution of Design," and he suggested that I should add the word "Architectural," making the subject "The Execution of Architectural Design." I accepted this because I felt that the limitation was a good one, although the subject might be misunderstood.

The expression Architectural Design is used generally and quite properly as describing an illustration of some specific thing or idea developed by an architect. I might, for example, refer to a drawing of a bank and say, "that is my design for a bank," but this is not the meaning I wish to give the expression here to-night.

The meaning may perhaps be conveyed more clearly if we say "purpose" instead of "design," and expand the title to read "The Carrying Out of Architectural Purpose."

An architectural design must be the work of a man who is actually, in so far as the design goes, an architect, even though he may not be an architect by profession. Architectural design or purpose may be conceived by any one, and is, in fact, generally conceived by some one who is not an architect.

It is well that this should be understood clearly. The original design, purpose, concept, or whatever we are to call it, is not the architect's. When a client goes to an architect he goes with a purpose or design in mind which he wishes to have executed, and it is about the execution of this design that I will speak to-night—about the parties who execute it and the instruments that are used to unite these parties in their undertaking.

There are two divisions of this subject—two periods of execution:

First. The period of expression.

Second. The period of action.

In the first period the parties interested are the owner, the architect and contractors.

The instruments of service are:

(1) The drawings.
(2) The specifications.
(3) *a.* The invitation to bidders.
b. The advertisement and supplement.
(4) The proposal.
(5) The acceptance.
(6) The contract.

In the second period the parties interested are the owner, the architect and the contractor.

The instruments of service are:

(1) The signed contract.
(2) The bond with its collateral (fire insurance).
(3) Architect's certificate.
(4) Release of liens, etc.
(5) Guarantees.

It will be noticed at once that in both periods the parties interested are called by practically the same names, but their functions are widely different. In the first period we have the owner, architect and contractor—that is, the conceiver of the purpose, the expresser of it, and the price-namer. In the second period we have again the owner, architect and contractor; but now they are the paymaster, the inspector and arbitrator in one, and the builder.

The first period is that which ends with the preparation of the contract and is taken by the owner or party whose purpose or design is to be executed with the assistance of the architect to express for him this design, and by a third party—which may be one or more contractors—who names a price for which the design can be executed, and who signifies his willingness to enter into a contract to execute it for the price he has named.

The second period commences with the signing of the

contract and is taken by the contractor with the assistance of the owner, who furnishes the money, and of the architect, who fills the position of superintendent of the work and arbitrator of disputes between the contractor and owner, about matters subject to his judgment or opinion.

It simplifies very much the first period, if all three parties remember that its end is the drawing up of an efficient contract.

As that contract is to express the owner's purpose, that purpose must be defined clearly or it cannot be expressed successfully.

As an illustration of this I may cite the problem of the dwelling house. This is one of the most difficult problems because each room should fit the need or purposed use of the occupant, and special needs cannot be foreseen unless expressed; so that an owner who knows only what rooms he wants and how much he can pay, cannot get the same sympathetic house as the owner who has clearly defined the life which his house must environ.

An architect may develop a house with the knowledge of what beautiful home-life ought to be, and this house may be a successful educator; but no house is so near the ideal as that which has been developed to fit the clearly defined ideas of the man who lives a beautiful life therein.

The architect may develop a house—the owner makes the home. Unless the house expresses the home-life, the highest purpose has not been reached. This truth applies to all the petty details of the problem. If the owner will have two servants or three; if he blacks his own boots; if he has many or few books; if he is fond of flowers—all these are things that he should know about himself, and knowing them, he should see that his house meets the needs of its master with the fullest opportunity he can command.

The architect, too, must remember that the end of this first period is the drawing up of an efficient contract. What are the drawings for? What are the specifications for? Why are bids asked and schedules prepared?

No matter how much he may enjoy the work, no matter how beautiful any of his drawings may be, he must face the

practical fact, that none of his productions are of value to the party for whom they are made except as they rightly express in the contract the purpose of that party.

As for the contractor, it is only necessary to state the proposition and hardly that. The difference in result is wide when a contractor estimates the value and bids to execute what he considers the purpose of the owner so that a fair value or price may be stated in the contract, and when he bids with the purpose of taking advantage of an inadequate expression of this purpose.

I shall refer again to the contractor and state the problem of his selection. This problem has not, to my mind, been satisfactorily solved.

Let us now look at the instruments that unite the three parties in the first period of the execution of architectural design—in the period of expression.

(1) THE DRAWINGS.

The first instrument developed is, of the necessities of the case, the drawings. The reason for this is apparent. As the drawings are a graphical projection, so to speak, of the purpose to be executed, and as they afford the only practical and adequate method of projecting in more than one mind the same ideas of this purpose, it is necessary that this projection should be made before the other instruments are drawn up.

The error of making estimates on general descriptions, no matter how carefully these may be worded, leads to the reduction of the standard of the practice.

The owner must say first what he wants and how much he is willing to pay for it. If he is not willing to say what he will pay for his building he should incur, without question, the expense of having what he wants drawn out sufficiently to enable an estimator to do something more than guess, in order to determine the scale on which his purpose is to be projected.

This is only one illustration of many that might be given of the importance of expressing by drawings the possibility of the problem before elaboration in other directions.

With reference to the drawings themselves, either how to make them express beautiful things or how to do this with beautiful draughtsmanship, I cannot speak to-night. I must say in passing that I believe it is an architect's first duty to express beautiful ideas and to give, where possible, to his clients the desire, if they do not possess it, of the beautiful. I must say also that I think it is well worth while to make beautiful drawings in spite of the fact that the finished product of an architect is not the drawings but the building.

The drawings should, however, as instruments forming part of the contract, be exact, and in order that they may be so a few rules are necessary:

(1) Nothing should be drawn in elevation without drawing it in section and plan, unless section and plan are so familiar that they can be clearly projected in mind without putting them on paper.

(2) The finished product is the building, and not the drawings, and nothing should be put on the drawings that does not have value to the estimator or builder, simply for the purpose of making a drawing pretty.

No sketching should be done on a working drawing. Texture, shadows, etc., may be shown, but they must be accurate and to scale.

(3) The question must be constantly asked, Do I know what is meant by this, and will somebody else understand it?

When the question arises, what things should be left for the specification, the answer to it can only be given in a general way. It is better to mark specific and exceptional cases on the drawings, as, for example: If a small roof over a part of a building not easy to identify by written description, is of sheet metal, and the rest is to be roofed with slate, it is wise to mark on the drawings the fact that this roof is covered with sheet metal. It is also better to leave for the specification the general statement that the roofs of the building are covered with slate, except in the case of the roof otherwise marked on the drawings. Apart from this general rule, questions answer themselves as they arise.

Certain details are much easier to show by drawings than

they are to describe by writing, and *vice versa*, and, keeping in view the essential of clearness, it may be said that where two methods are equally clear, the easiest method of description is the best; but it is the experience of most architects that unless the work is fully drawn out, it is not safe to depend upon the memory to suggest the things that are to be described.

(2) SPECIFICATIONS.

As it is not practically possible to describe thoroughly everything on the drawings, it is necessary to supplement these with a written description, which must cover not only the work to be done, but the conditions under which it is to be done, and this description is called the specification.

It is worth while at this point to note that the drawings and specification must pass into the hands of every one interested in the work, and, it may be, that certain conditions are of such a confidential nature, between the owner and the contractor, that it is not wise to spread them before the sub-contractors, mechanics on the building and others who may, through curiosity or necessity, examine them. Such matters are, the time of the completion of the work, the bond given by the general contractor to the owner, and other confidential points that may arise.

It often happens that the general contractor, as a matter of business precaution, requires his sub-contractors to finish the work they have to do for him long before he is required to finish the whole building, and to furnish greater security in proportion to the amount of work than that required of the general contractor by the owner. The general contractor, therefore, should not be handicapped by having such obligations as these put in the specification. They should be put in the contract proper; but, in order that he may know what he has to bid on, the amount of the bond, and the date of the completion of the work, if it is fixed at the time the invitations are sent out, should be stated in the invitation to the contractor when he is asked to bid. The specification states the business relations between the owner and the contractor, in as far as they relate to the method of carrying out the work, and should set forth

clearly how the work is to be superintended, and it should give, in a sort of preface, a general statement of the work to be undertaken, that the specification may be read intelligently from the beginning of the description.

We have now reached a part of this theme that has been with me so constant an object of thought for many years that I would like to enlarge upon it and perhaps give it undue prominence in this evening's work. I refer to the methods of the specification writer—to the difficulties of the work, and the great importance of the specifications as part of the contract.

The law of specification in philosopher's terms is this: "No matter how far specification is carried it can always be carried beyond."

This is the law under which the ancestor hunters seek their elusive game. Every ancestor they find justifies the belief that there are at least two more. And the genealogist after all is only writing the specification which, as it reaches back to ancient times, more and more fully describes the sources of our blood.

All specifications start with a statement that the work is to be complete, and all beyond is an amplification of this word complete.

Wherever there is more than one way to complete the structure the specification writer must know it and he must remember it. He must know also the best way and he must clearly describe it. His knowledge of the best way comes from education and experience, and these are both long stories. He can aid his memory by notes and, best of all, by method—by pursuing some regular order in writing.

As an illustration of this I think we can readily see that it is less difficult to remember the items of hardware if we specify all the hardware for doors first and then all for windows, and under the head of doors if we specify all the locks first and then all the hinges, etc., etc., than if we tried to mention these items without regular order. But it is sometimes hard to find the thread that will lead us through this maze, and, having found it, it is hard to stick to it; but I believe success lies only along this path.

The drawings and specifications together constitute the owner's statement of his requirements expressed by the architect.

(3*a*) THE INVITATION.

A formal invitation for bids usually states where information can be obtained—the time and place for the delivering of the bids and conditions of a more or less confidential nature that can not be put in the specifications, such as the amount of the security required.

(3*b*) ADVERTISEMENT AND SUPPLEMENT.

In the case of public work the laws generally require that the widest latitude be given in selecting bidders, so that the invitation usually takes the form of an advertisement in the public press. Advertisements of this sort are usually brief and often state no more than that information can be had at such a place with reference to work on which the City or Government requests bids. The work is described in general terms. For the information of parties making inquiry at the place named, a supplement which contains a schedule to be filled by bidders is prepared and given out so that inquirers, who are often only messengers, may have a pretty good general idea of what is to be bid on before taking a set of drawings and specifications which are too valuable to be distributed carelessly.

(4) THE PROPOSAL AND (5) THE ACCEPTANCE.

The proposal is a statement of the amount for which the maker will undertake to execute the design expressed by the drawings and specifications, and the acceptance is simply a statement by the owner that he accepts the proposal.

The more simple the proposal and acceptance are the stronger they are.

Two or three facts which I can give you on the authority of "Engineering Contracts and Specifications," by J. B. Johnson, C.E., Dean of the College of Mechanics and Engineering, University of Wisconsin, will show at once what important instruments the proposal and acceptance are.

In order that the contract shall be binding on both par-

ties to the agreement it must have been understood and assented to by both in the same sense.

This agreement is not consummated until each party has communicated his intention in the matter.

The person who makes an offer must allow a reasonable time for its acceptance and if the acceptance is returned by the same agency used in sending the offer, the contract is completed at the time the acceptance is delivered to this agent. For example, a proposition sent by mail is accepted at the time the letter of acceptance is deposited in the post-office or letter-box, and a proposition sent by telegraph is accepted at the time of delivery of a telegraph reply at the telegraph office or to a telegraph messenger.

When an offer is made by mail or telegraph these agents become the recognized agents of the party making the offer and that party is bound by their mistakes.

It is customary to state, in asking for bids for executing architectural design, that the owner reserves the right to reject any or all propositions.

The formation of a contract really dates from the transmission of the acceptance.

The formal contract is a recitation in brief of obligations undertaken by the contractor and owner and it should be as brief as it is possible to make it. The advantage of having these obligations on one paper signed by both parties—sealed and witnessed—is that it renders easy in case of dispute the proof of mutual assent, and avoids the necessity of proving that one party did accept the proposal of the other in a binding manner.

The drawing up of this contract completes the first period of the execution of architectural design.

With the signing of the contract the contractor becomes actually the most important party in the transaction. If the first period has witnessed that harmony and intelligence of action that (as I have stated) alone make for success, and if the contractor fulfils all his obligations, he alone is active; but as conditions are rarely so ideal, both owner and architect, as a rule, are fully occupied on the one hand in amplifying the expression of purpose, and on the other in

demanding the fulfilment of obligation. The fact remains, and it is a most important one, that the contractor is the one party through whom all the work is done. The finished building is the goal of the architect's efforts and of the owner's purpose. The owner pays for it, and rightly or wrongly the architect must take the moral responsibility for it, and yet after the contract is signed and until it is completed or annulled the contractor controls the destinies of the work.

I wish to emphasize this fact because it will help to make clear the statement of my problem of the selection of the contractor. As long as the latter remains a party to the contract, as the active worker, he dominates it either for good or ill. Even if he neglects it, his neglect becomes the dominant fact.

Because the contractor may be incompetent financially, or in some other way, it is customary to require security for the faithful performance of the contract. Asking this security is so customary a matter of business that it conveys no moral reflection or aspersion of character. This was not always the case. It was a matter of great pride with some of the older men fifteen or twenty years ago that they never gave bond. But the financial magnitude of architectural undertakings has made more general the practice of asking more than one party to unite to carry the financial responsibility, and since the first requisite of a good bondsman is that his value should be permanent, it is customary to find corporations acting in this capacity.

While the bondsman and the contractor unite in this way to protect the owner from loss, the owner becomes obligated to advise the bondsman of any change contemplated in the contract, and it is well for the owner to have the expressed satisfaction of the bondsman before making changes, or the latter may slip his obligations.

It is, of course, the practice to have the bond executed before any money is paid to the contractor, but it is better practice to demand the execution of the bond immediately after the execution of contract.

[*To be concluded.*]

Notes and Comments.

THE END OF THE MORRIS CANAL.

The famous Morris Canal in New Jersey is practically condemned in a report just rendered to Governor Murphy by ex-Governors Werts, Griggs, and Voorhees. The canal company was incorporated in 1824 and built this waterway soon afterward, from Phillipsburg on the Delaware River to Jersey City, a distance of 106 miles. A number of reservoirs were constructed, some of which are now summer resorts and surrounded by valuable estates. The State has a right to take the canal in 1974. It was leased in 1871 to the Lehigh Valley Railroad Company, which has since operated it. The eminent commissioners report that even were the property in perfect condition, it could not be operated at a profit. The decline in its value has been due to the construction of railways which became powerful competitors, carrying freight at cheaper rates than is possible with the canal boats except at a loss. Eventually all traffic was diverted from it except the trifling amount from the lessee. At the present time it stands in the way of needed public improvements, but its abandonment involves the untangling of a complication of interests, including the stockholders of the canal company, the lessor railroad company, the State, the municipalities along the route, the landholders about the reservoirs, and the people having contracts for important water rights, not to mention a lot of trifling claimants for consideration. While the abandonment is assured, it now appears that it will involve more trouble and delay than the original construction of this canal, once the pride of northern New Jersey.—*Engineering Record.*

TIN IN ALASKA.

From a valuable Bulletin lately issued by the U. S. Geological Survey we reproduce the following conclusions:

"The above facts show cassiterite to be rather irregularly distributed through an area of about 450 square miles, embracing the western end of Seward Peninsula. At three localities—Anikovik River, Buhner Creek and Buck Creek—its occurrence in placers has been verified by the Geological Survey, and lode tin has been found by the Survey at Lost River and at Cape Mountain. There are a number of other places where prospectors report its occurrence in lode or placer form. The tin ore is almost all cassiterite, though a little stannite has been found at one locality. Its original source is in deposits of at least two essentially different types. In the one it is in quartz veins, which cut phyllites or metamorphic slates; in the other the cassiterite is disseminated through more or less altered granitic rocks. This second type of lode deposit is the one which gives promise of commercial importance.

"In estimating the value of tin ores in this northern region several facts should be borne in mind. The region is utterly without timber, and is accessible by ocean steamers only from June to the end of October at the longest. Harbor facilities are poor, and all supplies and wages are high. On the other

hand, the construction of railroads and wagon roads is not difficult, and will require comparatively small outlay. All of the occurrences described are within a few miles of tidewater. Freight rates to Puget Sound ports should be very low, as the large fleet of ocean steamers which runs to Nome returns empty. Last summer upward of 98,000 tons of freight were brought to Alaska by vessels that called at Nome. It is fair to say that these tin deposits are well worth careful and systematic prospecting."

ELECTRICITY DIRECT FROM COAL.

R. Lorenz gives a capital summary of the present state of the problem of directly converting the chemical energy of burning carbon into electricity. The slow combustion involved in an electrolytic process such as is exemplified in an ordinary voltaic cell suffers under three disadvantages—viz., the slowness of the reaction between C and O at ordinary temperatures, the impurity of the carbon, which gives rise to complicated hydrocarbons in solution, and the necessity of using the highly-priced conducting forms of carbon instead of ordinary coal. These circumstances led to the adoption of a gaseous "electrode" consisting of carbon monoxide, as in the cells of Bucherer and Borchers. In these, however, the currents obtained cannot be proved to result from the further oxidation of the CO. Indeed, the existence of CO ions has yet to be demonstrated. Another and more indirect way of utilizing the energy of carbon is that suggested by Nernst, in which carbon is used for regenerating other cells, such as Daniell's cell, by the reduction of the zinc sulphate. Another method proposed by Nernst is to heat an accumulator having a negative temperature coefficient until its E.M.F. disappears and then let it cool. Dolezalek has, indeed, obtained an E.M.F. of 0·6 volt between two lead accumulators having a difference of temperature of 90°. The problem is theoretically soluble, but will require much detailed work for its final solution.—*R. Lorenz, Mitt. Phys. Ges. Zürich, No. 5, 1903.*

USES OF GILSONITE AND ELATERITE.

The uses to which gilsonite and elaterite are put are varied. There is a big shortage in the world's supply of vegetable rubber, and these hydrocarbons are now taking its place. They are made into a mineral rubber that unites perfectly with tree rubber, thus permitting a very large reduction in the amount of the latter used, and cheapening its cost materially. Second-grade gilsonite is used for paving cement by melting it with petroleum residue and mixing it with ground asphaltic limestone and the requisite amount of sand. Gilsonite is also manufactured into varnishes, lacquers, waterproof paint for gun carriages, and steel and wood work of every description known to ship building; as a paint for ship bottoms, it prevents barnacles from attaching themselves. It is also used for pipe coatings, reservoir coatings, floorings, roofings, and railroad work. The following is a further list of some of its uses: For coating barbed-wire fencing; coating sea walls of brick and masonry; coating paving brick; acid-proof lining for chemical tanks; roofing pitch; insulating electric wires; smokestack paint; coating poles, posts, and

ties; lubricant for heavy machines; covering wood-block paving; binding pitch for carbon in making coal briquettes.

Elaterite is being largely used now to make flexible and heatproof varnish and paints, which are excellent for coating shaft and tunnel timbers, for painting hemp and wire hoisting ropes, pump columns, pipes, chains, ore cars, and all steel and iron work where the surfaces are exposed; also for coating vats, tanks, and pan covers used in chlorination works, smelters, and refineries, and in the cyanide process. On ironwork it prevents corrosion and resists great heats. On woodwork it prevents absorption, and defies the elements.—*Mines and Minerals.*

TURBINE OCEAN STEAMERS.

Although the construction of the great turbine-propelled liners for the Cunard Company overshadows in public interest every other marine turbine development just now, it is a fact that there will be some splendid specimens of turbine ocean liners in service on the high seas long before the Cunard vessels are in the water. Mention should be made incidentally of the "Turbinia," which was launched not very long ago in Great Britain, and will soon cross the Atlantic for service on Lake Ontario. Before many weeks a large ocean steamer, the "Tasmania," will be dispatched to Australia, and the Allan Line will place two turbine-driven liners in the Atlantic service of the company. Next year, moreover, a turbine-driven Cunard steamer of about half the tonnage of the 25-knot 40,000-ton turbine ships will be plying between Liverpool and the United States. Considering that the practical turbine is but a decade and a half old, this must be considered a remarkably rapid development of what is commercially considered an entirely new type of steam engine.—*Scientific American.*

URANIUM.

Uranium is one of the rare metals for which there is a limited demand. The present world's consumption amounts annually to about 300 tons of uranium ore, yielding from 3 to 13 per cent. of the metal. For several years Colorado has supplied the United States output, nearly all of which goes to Europe. France, England, and Germany are the principal markets. Uranium is a hard, very heavy (9·184), moderately malleable metal; it resembles nickel and iron, and has the color of nickel. At ordinary temperatures it is not affected by air or water; at red-heat, however, the surface oxidizes. The chief ore of uranium is the oxide, called pitchblende or uranium. It occurs also as the phosphate and arsenate. The ores are found in Gilpin and other counties of Colorado; in Cornwall, England; and in Saxony, Germany. Buyers of the ore generally pay from $15 to $20 per unit, according to the percentage of uranium contained. Until recently uranium salts were used chiefly as a pigment in painting on porcelain, in photography, and as a coloring ingredient in glass manufacture. It is now being used experimentally in the manufacture of alloys of iron and aluminum. Uranium increases the hardness and elasticity of steel, and also the hardness of aluminum, but this use has not yet become sufficiently important to cause an increased demand for the metal. —*Engineering and Mining Journal.*

Book Notices.

Electric Traction. A practical handbook on the application of electricity as a locomotive power. By John Hall Rider, Chief Electrical Engineer, London County Council Tramways, M. Inst. C. E., etc. With 194 illustrations. (8vo, pp. xvi + 453.) London and New York: Whittaker & Co.

This volume forms one of the "Specialists' Series," a useful series of handbooks for engineers, issued from the publishers' press.

It is designed to supply the operative engineer with such information respecting the general underlying principles, the construction, equipment and operation of electric railways, as will be likely to prove directly serviceable in his everyday practice. The American specialist will doubtless find it useful as a source of data for comparison with American practice. The work is excellently printed and illustrated and elaborately indexed. W.

Elements of Geology. A text-book for colleges and for the general reader. By Joseph Le Conte, author of "Religion and Science," etc. Revised and partly re-written by Herman Le Roy Fairchild, Professor of Geology in the University of Rochester. Fifth edition, revised and enlarged, with new plates and illustrations. New York: Appleton & Co. 1903. (Price, $4.00.)

It is no easy task to take from the hand of the deceased author one of the four most celebrated text-books on geology in the English language and revise and bring it up to date without allowing the patches to be seen, yet Professor Fairchild, the widely celebrated Secretary of the Geological Society of America, has accomplished it. It might be supposed that so enthusiastic a convert to the new earth chapter of the Nebular Theory of Professor Chamberlin, would inject a great deal of this view into the text, but the only place in which direct reference to the new hypothesis is made occurs on page 295 in two paragraphs on Pregeologic Eras.

The book is well printed on fairly good paper and the illustrations are apt and clear, though some of the older cuts appear to have been "thrown up" from a previous impression. It would have been more in conformity with modern tendency to spell "Archæan" and "Palæozoic," "Archean" and "Paleozoic," or, if the reviser preferred to retain the diphthongs in these words, to have dealt likewise with Cenozoic, which is entitled to the Greek ai in Kainos (new), as much as Archaios (ancient) and Palaios (old).

F.

United States Magnetic Declination and Isogonic Charts for 1902, etc. By L. A. Bauer, Chief of Division of Terrestrial Magnetism. Government Printing Office, Washington, D. C. 1902.

Since the observation of terrestrial magnetism was made a fundamental part of the work of the U. S. Coast and Geodetic Survey in 1855, isogonic charts (those showing the course over the earth's surface of lines of equal magnetic deflection (declination) east or west from the true north) have been published for the following epochs: 1850, 1860, 1870, 1875, 1885, 1890, and 1900 (the last published in 1897). No official publication in this or any other country has exceeded these publications in originality, accuracy, and patient

mathematical computation. The present volume surpasses all the others in detail as in size. It is preceded by a very interesting chapter on the principal facts relating to the earth's magnetism, in which a complete but succinct history of the discovery of all the phenomena observable in the lodestone and magnetized needle, the invention of the compass and its improvement, and the reproduction of the earlier and some of the later isogonic charts from Hansteen for 1600 and 1800, Halley for 1700, and the British Admiralty for 1858 and 1905. The book is filled with descriptions of the magnetic stations by States and tables of observations, and well illustrated by half-tones of the former and of the instruments of the past and present. F.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, June 15, 1904.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 15, 1904.

PRESIDENT JOHN BIRKINBINE in the chair.

Present, 145 members and visitors.

Additions to membership since last report, 13.

Rear-Admiral Geo. W. Melville, U. S. N., was introduced by the President and read the paper of the evening on "The Naval Strength of the United States."

The President expressed the thanks of the meeting to the speaker.

Mr. Julian Florian, of New York, gave a brief description of "The Cellutype," an improved apparatus and process for the production—automatically—of positive photographs. The inventors are Messrs. Julius Gregory and Julian Florian. The speaker illustrated the subject of his remarks by a number of practical demonstrations with the machine.

Adjourned. WM. H. WAHL,
Secretary.

Committee on Science and the Arts.

(*Abstract of the proceedings of the stated meeting, held Wednesday, June 1, 1904.*)

PROF. LEWIS M. HAUPT in the chair.

The following reports were adopted:

(No. 2320) *Tent Fastening.* James J. Rinn, Philadelphia.

ABSTRACT: The invention consists in the use of rigid strips fitted with a simple form of catch to hold them securely together for the purpose of fastening entrances to tents. The device was shown in model for use both on the ordinary round (or bell) tent and on the wall or A tent.

The invention is secured by letters-patent of the United States Nos. 528,391, 2, 3, and 4, under date of October 30, 1894, granted to applicant.

The device can be applied to any tent without requiring any expensive changes or additions to the structure, and commends itself as one admirably adapted to add to the ease and comfort of tent-life.

The closing of the entrance to a tent is often very troublesome in windy or wet weather, and egress and ingress is often a serious inconvenience. With this device the tent can be left and entered practically as easily as through a regular door, and, in addition, the device appears a ready means of leaving the whole front of the tent open, with no loose parts to flap about and gradually shake fastenings loose.

The opinion is expressed that the device has merit and utility, but in view of the fact that it has not yet been applied in practice and tested, the committee recommends the award at this time of a Certificate of Merit. (*Sub-Committee*, T. Carpenter Smith, Chairman; W. W. Canby, C. E. Ronaldson, James E. Rogers.)

(No. 2323.) *Methods and Apparatus for Detecting Corrosion of Metals by Electrolysis.* Adolphus A. Knudson, New York. An advisory report.

(No. 2328.) *Coal Storage Structure.* James M. Dodge, Philadelphia.

ABSTRACT: This invention is protected by U. S. letters-patent No. 539,250, May 14, 1895, granted to Mr. Dodge. Its object is to so construct bins (for storing coal or analogous materials in large quantities) that, although they be built of comparatively light materials, will be so formed and braced as easily to withstand the pressure of the material piled within them. (Not adapted for intelligible abstraction except by means of illustrations.)

In recognition of the originality and simplicity of the mechanical methods employed by the inventor, and the demonstrated utility of the invention as an economical and efficient substitute for the ordinary methods of storage, the report recommends the award to the inventor of the John Scott Legacy Premium and Medal. (*Sub-Committee*, Chas. E. Ronaldson, James Christie, John M. Hartman.)

(No. 2326.) *Feed-Water Regulator.* Amos E. Burrows, York, Pa.

Passed second reading, discussed, and referred back to sub-committee.

The following passed first reading:

(No. 2281.) *Reducing the Attenuation of Electrical Waves.* Michael A. Pupin, New York.

(No. 2307.) *Automatic Electric Semaphore Signal.* J. William Lattig, Wyncote, Pa.

Referred back to sub-committee for information.

(No. 2309.) *Automatic Electric Safety-Block and Train-Control System.* Dr. Samuel D. Strohm, Philadelphia.

(A report of progress.)

(No. 2316.) *Reconstructed Milk.* C. H. and P. T. Campbell, Jersey City, N. J.

(No. 2321.) *Alumino-Thermics.* Dr. Hans Goldschmidt, Essen, Germany.

(No. 2186.) *Tangential Water-Wheel.* Wm. A. Doble, San Francisco, Cal.

Notice is given of a motion to reconsider the report.

Dr. W. J. Williams, a newly-elected member (*vice* Dr. H. Leffmann, resigned), is presented to the Chair and takes his place in the meeting.

W.

JOURNAL

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VOL. CLVIII, No. 2. 79TH YEAR. AUGUST, 1904

THE FRANKLIN INSTITUTE.

Communicated by the Author to the Stated Meeting, held Wednesday, April 15, 1903.

The Mine Explosion at Johnstown.

BY M. G. MOORE,
Mining Engineer in charge of the Mining and Coking Department of the Cambria Steel Company.

On the tenth day of July, 1902, there was an explosion of fire damp in the Rolling Mill mine of the Cambria Steel Company at Johnstown, Pa., which resulted in the loss of 112 human lives, and was, in this respect, probably the most disastrous that ever occurred in the State of Pennsylvania.

The explosion presents some such peculiar features that a statement of the facts relating to it may possibly be of interest to the members of the Institute.

DESCRIPTION OF ROLLING MILL MINE.

The Rolling Mill mine was opened by the Cambria Iron Company in 1856 to supply their mills and works with coal and, with the exception of the two years of 1888 and 1889,

when natural gas was abundant in Johnstown, has been in continuous operation. At first the tonnage was small, and the workings remained without system until 1874, when the general method of mining now in use was adopted. The output was gradually increased, as the Cambria Works grew, from an average of 120 tons per day in 1857 to 2,600 tons per day at the time of the explosion. All the coal produced is used at the works of the Cambria Steel Company at Johnstown. The mouth of the mine is in a steep hillside on the left bank of the Stonycreek River just above its junction with the Little Conemaugh, 42 feet above the river bed and 1,209 feet above tide. The thickness of cover on the coal, which is known as bed C, or cement seam, varies from a maximum of a little over 500 feet to a minimum of 70 feet over a small area where a mountain stream cuts partially through the measures. Over the greater part of the mine the cover exceeds 300 feet in thickness. The roof of the coal is generally a seam of tough slate, varying in thickness from 2 inches to 10 feet; over this is a quite compact sandstone about 15 feet thick. The remaining cover is shales, sandstone, coal and limestone in well-defined stratas of varying thickness. When the mine was opened no machinery was used and, owing to the difficulty of keeping the dip workings unwatered, nearly all the extensions were made to the rise until 1892, when an electric pump (abandoned in 1898) was installed to unwater the lower side of the mine. Mining in the dip was not extensive until what is known as the Klondike Section, where the explosion occurred, was opened in 1897.

The thickness of the coal varies from an extreme of 5 feet in the dip workings to a minimum of 3 feet on the hill headings and has a dip to the southeast averaging about 4 per cent. Local swamps and basins are occasionally encountered necessitating considerable pumping.

The system of mining followed is known as the "pillar and stall." The main heading is driven nearly on the strike of the measures and as a general thing the cross headings are driven directly to the rise or dip, as the case may be, and the rooms on the strike. In the Klondike district it

was found advisable to drive the main heading to the dip, the cross headings on the strike and the rooms to the rise of the seam. The headings are driven 15 feet wide, the rooms 27 feet wide and about 300 feet long, and the pillars between the rooms are left 30 feet thick with cut-throughs at least every 90 feet. The main heading into the hill is 3·35 miles long, which is practically the extreme length of the mine. The extreme width is 1·78 miles and the area mined out 2,300 acres, of which about 60 per cent. is on the right or to the rise and 40 per cent. on the left or dip of the coal.

Near the end of the main heading in the valley of Mill Creek, 3·1 miles from the mouth of the mine, there is a second opening and ventilating shaft, 10 x 23 feet and 77·3 feet deep. On the surface over one compartment, which is 10 x 10 feet, there is a Cappell blowing fan 16 feet in diameter by 5 feet face, run by a direct connected 20 x 18-inch horizontal engine. The boiler pressure is 120 pounds per square inch and the engine valve cuts off at about one-third stroke. The engine runs normally at 112 revolutions, forcing 130,000 cubic feet of air per minute down the shaft into the mine against a water pressure of about 2 inches. The other compartment of the shaft is fitted with a hoisting carriage, operated by a small pair of winding engines, to supply the power-house with coal, and a subdivision of it is fitted with easy steps and landings from bottom to top for use in case of an emergency. About 150 feet west of the shaft there is a power-house containing four air compressors, two low pressure and two high pressure, together with 1,200 horse-power water-tube boilers, with the necessary coal bins, pumps, heaters and an elaborate system of piping. The entire plant is modern in every way, the machinery is of the best, and the main building, which is substantially constructed of stone, steel, slate and concrete, is 43 x 162 feet in size. The low-pressure compressors furnish air at a pressure of 90 pounds per square inch at the power-house for use in the mine for mining machines and pumping. The high-pressure compressors furnish air at 900 pounds per square inch, for operating pneumatic locomotives, of which

there are four in the mine. The low-pressure air is carried to the face of each working-room and heading by $1\frac{1}{4}$-inch iron pipes laid from mains that are from 3 to 7 inches in diameter. There is about 95 miles of low-pressure pipe and 4 miles of high-pressure pipe used to convey and distribute the compressed air to and in the mine. There is also a second opening in the valley of the Stonycreek River, 1,100 feet south of the main entrance to the mine.

Near the mouth of the mine there is a power-house containing boilers and a pair of 20 x 30-inch tail-rope engines, used to haul the coal in trips of seventy cars each from the main siding in the mine, 7,300 feet from its mouth, to the tipple, a total distance of about 10,000 feet. All of the machinery and appliances in use are of the latest pattern and every precaution was taken to assure a thorough ventilation of the entire mine. The airways are all of large area and the velocities of the air currents are low. The air for ventilation is distributed through the mine in splits as required by the law of 1893. The Superintendent's office, the Mine Foreman's office in the mine, both power-houses and the tipple, have telephones and are connected through the exchange of the Cambria Steel Company with the city exchange. The Cambria Company has always been most liberal in providing machinery, tools and appliances to make their mines safe, modern and economical to operate. It has spared no expense to secure the safety of the employees, and with the precaution taken and with the large volume of air in circulation and the rigid rules enforced it was impossible to have such a disaster, except through the criminal recklessness or disobedience of an inside employee.

At the time of the explosion about 650 men were employed in and around the mine. Of these probably 580 were inside men and possibly 450 were in the mine at the time of the accident. The inside men who were not working that day were either on night turn or were idle for some cause. Including drivers and laborers there were in the Klondike at the time of the explosion about 150 men, working in three separate splits of air with a circulation respectively of 20,000, 18,000, and 8,000 cubic feet per minute.

When the Klondike Section was opened to the dip on the left, in 1897, a little gas had been found in the rib workings on the right or high side of the mine; but as the pillars were drawn back and the roof fell in and the area of the gob increased the gas had always disappeared. This was probably due to a more permeable strata of cover being exposed as the slates caved in and allowed the gas over the falls to escape through crevices to the surface. In fact, there was so little gas on the right-hand side of the mine that it was hardly considered, although fire bosses were always employed to look after the safety of the men. The face of the Klondike heading at the time of the explosion was 4,650 feet from the main heading. On the right side four pairs of cross headings had been driven off, practically on water level, and on the left there were five. All the work was opened originally on the double-heading plan, but after explosive gas was encountered the three-heading system was adopted where possible. A third heading or airway was sometimes made by utilizing the abandoned rooms next to and parallel to the main heading.

Of the two maps shown, the outline one is the entire mine at a small scale with the Klondike portion shown by the heavier shading. The other is a detail map of the Klondike. The star indicates the point of origin of the explosion, the crosses the location of the bodies found and the arrows the direction of the air currents. It will be noted (see map of Klondike Section) that between the fifth and sixth headings on the right side coming down there are about 2 acres of gob where pillars had been drawn; beyond this, toward the face of the headings for some distance, are abandoned rooms, then come working-rooms and then the faces of the headings.

All the walls that guide or confine the air were made of brick or slate and cement mortar; all air bridges were made of steel and brick; all important doors were in duplicate and the ventilation was considered to be without a flaw. The mine was always considered to be safe, as will be seen by the following paragraph from the report of the Chief of the Bureau of Mines for the year 1901:

"Ten mines are located in and about Johnstown; some of them are small, but all are well ventilated and drained, and consequently are in good sanitary condition. Five are operated by the Cambria Steel Company, all of which are equipped with the best kind of ventilators. The safety of the mines at this point can be judged by the fact that over 1,000,000 tons of coal were produced during 1901, and but one fatal accident occurred, that being in the Rolling Mill mine, the largest single operation in the district, which produced over 601,000 tons during the year."

EXPLOSION.

The explosion, which was not severe, occurred about 11.20 A.M. in No. 2 room of sixth right heading off the Main south or Klondike heading. There were two men working in the room and five others in the immediate vicinity, all of whom had been given safety lamps in the morning by the fire boss of that section, and were seen going into their rooms with them. The fire boss had made an examination of this place some time previous to 7 o'clock. He found gas as usual on the gob and recorded it in the daily report book at the office. As gas was expected and had been found in that locality for a long time, no precautions other than the usual ones, which were considered ample, were taken that morning. The fire boss had received special instructions some time before to note if the gas was getting stronger, but as he had said nothing about it and as the records, which he faithfully made, show no essential changes, it is safe to infer that the quantity of gas had not increased perceptibly for several months. This is confirmed by the mine foreman, who had examined the place the day before. As the fire boss in charge of this district, in company with others, went into the Klondike after the explosion and lost his life while aiding in the work of rescue, nothing positive concerning the condition of the gas on the morning of the explosion is known other than what is shown by his report book, the record in which was made about four hours before the explosion. The four fire bosses always entered the mine at 3 o'clock in the morning, and each of them examined

all the working places and roads of the district under his charge. They then went to the inside office, entered the result of their examination upon the book, reported verbally to the mine foreman and attended to giving out the safety lamps and getting the men started to work. After the men had all gone to their working places the fire bosses always made a second trip through their respective districts to see if everything was safe, and that all of the men who had been given safety lamps were working with them, and to note any dangers that might have arisen since the time of their first visit. This routine was observed on the morning of the explosion. The fire boss of Klondike and the others returned to the mine foreman's office from their second examination about 11 o'clock; but, as they made no further report to the mine foreman, and made no changes in the written report they had all signed in the early morning, the only inference that can be drawn is that they found everything in a safe and satisfactory condition. The fire boss in charge of the Klondike district was an elderly and especially trustworthy man, who had been employed by Cambria for many years. He had been assigned this more dangerous district on account of his known carefulness and ability, and had he found anything wrong or any unusual condition upon his second round he would undoubtedly have at once taken the men out of the danger and reported the fact to the mine foreman. As he did not do this and said nothing about any changed conditions, it is impossible to believe that he discovered anything out of the way on his second examination.

The men who were working in room No. 2, where the explosion originated, were German Poles, who spoke English fluently. All of them had been employed in Rolling Mill mine for a number of years, and as they had seen the danger constantly and their attention had been called to it frequently, it is impossible to consider them unfitted to work in that place. They had been selected especially for this locality only three days before on account of their superior intelligence and long experience in the mine, after a consultation of the fire bosses and mine foreman. The work of

drawing back the pillars from the sixth heading side, where the men were working, had been started only two days before and, as gas was known to exist, especially careful men were wanted to work in this locality. The seven men who were working there were in rooms Nos. 1 and 2 sixth right and rooms Nos. 1 and 2 long wall, and four of the seven were "butties" or partners. The explosion was felt at the mine foreman's office, which is at the entrance of the Klondike section, just as the four fire bosses were starting out of the mine. The mine foreman immediately sent word to them to come down into Klondike as there had been an explosion, and without a moment's hesitation they, together with the labor boss, mine foreman, assistant mine foreman, machine boss and an assistant fire boss, procured safety-lamps and went into Klondike to restore the ventilation and get the men out. The explosion was so slight that all who heard it at the mine foreman's office thought it was not serious, but to be on the safe side the mine foreman started his assistants to notify the men on the right-hand side of Klondike to go out. They found a number of doors blown down and while some of the officials were trying to replace them, and while others were endeavoring to warn the miners, the poisonous after-damp came upon them, and of the nine who went down, but two succeeded in escaping, and of the remaining seven, five lost their lives. The mine foreman and machine boss were removed from the mine unconscious and after a long siege at the hospital recovered. The fire boss of the Klondike district died in the hospital ten days after the explosion without at any time fully regaining the use of his faculties.

The result of the explosion was not disastrous to the mine. No damage was done except that all the doors on both sides of Klondike, of which there were twenty-one, were blown down and all the stoppings between the sixth and seventh headings and some between the fourth and fifth were blown out. The doors were not blown to pieces, but thrown down flat. The stoppings consisted of brick walls laid in cement, or of double walls 4 feet apart built of flat slate with the inside space filled with coal dust and the outside

plastered with cement to make them air-tight. The mine was damaged so little that cost of replacing all the doors and stoppings damaged or blown out and all other repairs did not amount to $1,000, and mining operations were resumed on the fourth day after the explosion. The only men that were burned by the explosion were the seven working in the vicinity of the body of gas. A few of the others were instantly killed by being blown against the pillars or gob, and the remainder were all suffocated by carbonic oxide gas.

A careful examination of the workings established the fact that there was a body of gas, which had been reported, on the gob between fifth and sixth right headings, which was probably nearly in its pure state, and when ignited in some manner by the criminal recklessness and disobedience of the men in No. 2 room, burned comparatively slowly, and as oxygen was not supplied in sufficient quantity for complete combustion, burned to carbonic oxide, of which authorities say one-half of 1 per cent. in the air will produce death in one-half hour. There was undoubtedly a very much higher percentage of this poisonous gas in the air which met the miners of Klondike as they tried to escape, as the most of them fell to the ground apparently without a struggle. The stoppings being blown down and the ventilation destroyed the poisonous gas advanced slowly through the workings and headings and cut off the escape of the men who delayed leaving their working places. The careful examination of the mine after the accident showed that the explosion was not complicated in any way by coal dust exploding. The coal contains but 17 per cent. of volatile matter, and dust as low in volatile matter as this is not apt to explode unless suspended in the air in large quantities and subjected to high heat and concussion. The Klondike portion of Rolling Mill mine was quite damp and there was little or no dust suspended in the air.

The greater number of the victims were found on their way out of the mine with their coats on and their dinner buckets in their hands. Those working on the left side of Klondike and in the fifth heading on the right side of

Klondike, after they heard the explosion, carefully put their tools away, put on their coats and leisurely walked out of their rooms into the poisonous atmosphere. One miner testified at the inquest that he was working in a room off the fifth right heading when the explosion occurred; the concussion of the air knocked him down and extinguished his lamp, but he relit it and went back to work. Shortly after one of the fire bosses, who later lost his life, came in and ordered him to go out of the mine at once, which he did, but had a very narrow escape. On the left side of Klondike there were about sixty-three men working; among them were three pair of brothers, Americans, English and Irish, and all very intelligent men, who operated mining machines. Some time after the explosion when the air commenced to get bad, they opened the low pressure air pipes with their valve keys, so that the compressed air would blow into the faces of three rooms, and tried to get the men into these rooms, where they would be in the pure air that came from the pipes. This air was carried in the pipes at a pressure of something less than ninety (90) pounds per square inch, and it is estimated that nearly five times as much air came from the three open pipes as was necessary to preserve the lives of all these men. It was the next afternoon before the rescuing parties were able to get into the left side of Klondike, where they found only fifteen of them alive. Those still living were found at the end of the air pipes, the others, dead or dying, were found all sitting or lying at the mouth of Room No. 17 on the fourth left. Why these men left the faces of the three rooms where there was plenty of pure air and went into the poisonous gas on the heading is inexplicable. A number of them who were rescued were questioned, but their stories disagreed, so that it is impossible to draw conclusions that will satisfactorily explain their action. The men working in the other districts of the mine did not hear the explosion and did not leave the mine until ordered out by the officials, or until they discovered through not getting cars to load that the mine was shut down. Had the concussion been more severe it is very probable that it would have been so alarm-

ing that all of the men working on the left side of Klondike would have hastened from the mine without delay, and thus probably reduced the appalling death list by perhaps two-thirds.

It is a mystery what caused the gas to come in contact with the naked lamps in Room No. 2. It would be possible to account for it by an extensive fall of roof over the gob, but an examination after the explosion showed no fall of magnitude, and as it was shown that the miners working with naked lights had no occasion to go into the gob, the ignition of the gas will probably forever remain a mystery. The mine inspector had examined the mine on the 2d of June, five weeks before the explosion, and could find no fault with it in any way, and made a flattering report of its condition to the Chief of the Bureau of Mines.

THE WORK OF RESCUE.

The officials in charge of the Mining Department of Cambria received word of the explosion a little over one hour after it happened, but the magnitude of the calamity was not known until after they had gotten into the mine and met the after-damp on the main heading coming out with the air. When the extent of the disaster was realized the other mines of the Cambria Steel Company at Johnstown were at once stopped and the foremen and bosses, together with the competent English-speaking men, were rapidly driven to the escapement shaft at Mill Creek, 7 miles, to aid in the rescue.

Promptly after the explosion the fan was by telephone orders speeded up to 220 revolutions, forcing about 250,000 cubic feet of air per minute into the mine. Men were kept at the bearings and oil was used freely so that none of the bearings of engine or fan were unduly heated. The compressors were kept running constantly and the pressure in the two air-pipe systems maintained at 90 and 900 pounds per square inch respectively until the third day after the explosion, when the mine had been fully explored. This precaution undoubtedly resulted in the saving of the lives of

the men in the fourth left who remained in the faces of the rooms where the air-pipes were open.

When the officials of the Cambria Steel Company reached the mine and grasped the situation, brattice cloth, tools, and physicians with cans of oxygen, were immediately ordered and the work of rescue begun in a systematic way. The first regular rescuing party, led by the superintendent, went in the Klondike with physicians and cans of oxygen at about 4 P.M., and pushed ahead of the parties who were putting up brattices, to restore the ventilation. They succeeded in reaching some of the men on the Klondike heading who were still living, and by a liberal use of oxygen, quick trips to the hospital and faithful work on the part of the physicians and nurses, a number were resuscitated. Others were too far gone. The first efforts were to find the living; no attention was given to the dead other than a hasty examination. When life was found to be extinct the party passed on, searching for the living. Others were engaged in stretching brattice cloth and putting up stoppings to restore the ventilation as far as possible. This work was continued systematically night and day until the entire Klondike region had been thoroughly explored. Several attempts were made to enter the left side of Klondike the night of the 10th and morning of the 11th, but the air was in such a condition that it was impossible to live inside the entrance of the cross headings, and it was not until the afternoon of the 11th that a rescuing party, headed by the superintendent, succeeded in finding the men who had collected in No. 4 heading. There were physicians with cans of oxygen with all the rescuing parties and a number of lives were saved by their efforts in the mine. The last bodies removed from the mine on the evening of the 12th were four that had been located on the night of the 10th, but, owing to the rescuers confusing two of the heading numbers, had not been moved. There were about 150 men working in their places in the Klondike at the time of the explosion; of these about 100 lost their lives, 50 escaped, and the remaining 12 are accounted for by the lives lost in the mine foreman's party and by the fact that a number of laborers

went into Klondike after the mine foreman and his party to help restore ventilation. There was circulating in this portion of the mine about 46,000 cubic feet of air per minute, or more than 100 per cent. in excess of the requirements of the mine law.

The Board of Mine Inspectors appointed by the Chief of the Bureau of Mines of the State made a thorough examination of the mine on the 13th, or the third day after the explosion, and on the two following days. In room No. 2, sixth right heading, on their first trip, they found two common miner's lamps and a miner's cap lying near the face of the workings, and another party found shortly after the explosion, while the bodies were being removed, two safety lamps standing alongside of the road, not far from the face of this room, that had evidently been placed there before the explosion. About two months after the inquest a driver made affidavit to seeing the two men in Room No. 2 working with naked lights about ten minutes before the explosion, but he did not report the matter. During the investigation this driver was probably afraid of getting into trouble for not reporting such a gross violation of the Mine Law, so this evidence was not brought out at the inquest.

THE INQUEST.

Shortly after the accident the Coroner impanelled a jury, and the bodies were viewed at the morgue, as required by law. The inquest began on July 23d, and continued for five days. During that period there were thirty-four (34) witnesses called. The investigation at once took a very wide range, and many of the older miners and employees who were familiar with the conditions in the mine, both before and after the explosion, and many others, and all of the mine officials were called upon to testify. It was clearly established that the men working in the rooms where the explosion originated were given locked and lighted safety lamps that morning and took them into their rooms. It was also shown that no defective safety lamps were ever given out, and that no unlocked ones were given out except to experienced men who were authorized to fire blasts.

The last witnesses called were the four mine inspectors, constituting the board that had been appointed by the Chief of the Bureau of Mines to examine the mine to determine and report upon the cause of the explosion. Their report showed conclusively the point of origin of the explosion and its cause. Their testimony and the report was based upon three careful examinations of the mine after the explosion, and the facts observed during the frequent visits of the inspector of the district in which the mine is located. They discovered conclusive evidence that the mining laws and rules of the company had been deliberately and wilfully violated by the men working in room No. 2 sixth right heading, and stated so in their report, which was very complete, impartial and thorough, and showed careful attention to all the obtainable facts relating to the management and operation of the mine and all the conditions surrounding it. The general testimony showed that all of the mine officials and foremen were without exceptions experienced, sober and competent men, holding certificates of competency, and that they all knew of the dangers generally surrounding mining operations, and that they had always fully realized the responsibilities resting upon them. The jury, after deliberating carefully, returned the following verdict:

"We find that these persons (naming them) came to their death as the result of an explosion: that said explosion was caused by person or persons to the jury unknown by taking into room No. 2 sixth right heading, where gas was known to exist, open lamps, and using same in direct violation of the mining rules and regulations of the Cambria Steel Company."

It was shown during the inquest that the Cambria Steel Company had, through their officials, taken particular care to guard against the dangers that might arise in the mine from gas or other causes. Copies of notices calling the attention of each individual man in the mine to the dangers connected with explosive gas were shown, and it was further shown that every inside man had received one of these notices printed in the language with which he was most familiar. A large mass of correspondence between the management and the mine officials, extending over a period

of nearly three years, was shown, in which the mine officials were constantly urged to take every possible precaution for the safety of the men, and were instructed to make any demands upon the company for supplies, machinery, appliances or tools needed to make the mine safe and healthful. Some of the letters called attention to accidents at other mines, and pointed out the lack of attention and care brought out by the different Coroners' inquests held on the bodies of men killed in mine explosions, and cautioned the mine officials against taking risks or hesitating at any expenditure necessary to make the mine safe. These letters were all written in such a way as to bring replies and acknowledgments from the mine officials to the management, showing that they thoroughly understood the conditions and were taking all precautions possible, and that they all realized their responsibilities, and that their first duty was the safety of the men, and that in case of any doubt they were always to take the safe side if it closed the mine down at once.

The only precautions that have been used since the accident that were not taken before, are the absolute prohibition of the use of naked lights in the Klondike region. This portion of the mine is now operated exclusively with safety lamps, but it is only by extreme watchfulness that it is possible to keep naked lamps out of it and make the men strictly obey the rules. One miner was detected smoking in the Klondike in a dangerous place within three months after the explosion, and is now serving a sentence in the county jail for his violation of the mining law.

Each of the victims of the explosion carried one thousand ($1,000) dollars insurance in the Cambria Mutual Benefit Association, whose accounts are guaranteed by the Cambria Steel Company, which was paid to their families in addition to burial fees. A subscription was started and a small fund collected for the dependent families, but it was quickly seen that it was unnecessary, as their temporary wants were all provided for by the Cambria Steel Company, and the insurance money would be paid to them as soon as the necessary legal formalities could be complied with.

I have outlined as briefly as possible in the above the essential facts relating to this terrible disaster, and can only add that there will probably be such accidents, of a more or less serious nature, as long as only human beings are depended upon to work in the mines. Every precaution was taken at this mine that could be thought of to prevent a disaster, but the inexcusable disobedience of the strict rules by one employee resulted in his death and that of over one hundred of his fellow-workmen.

JOHNSTOWN, PA., April 6, 1903.

MECHANICAL APPLIANCES AT BLAST FURNACES.

The use of mechanical appliances for handling raw materials and fuel at blast furnaces, and of casting machines for the iron product, has made such an advance that it is estimated by good authority that a modern furnace can turn out 10 tons of finished product with the same number of workers that was needed to turn out 1 ton forty or fifty years ago.

PRECIOUS METALS IN THE ARTS.

One of the difficult problems to solve is the determination of the quantity of gold and silver used in the arts. The statistical departments of several European countries have tried to solve this problem, and have given it up. The U. S. Treasury Department has for several years endeavored to get accurate statistics on this point, but its figures are still far from complete, chiefly because it is impossible to determine the quantity of coin melted by jewelers and others. There seems to be a special secretiveness developed among those who use gold and silver in their trades.—*Engineering and Mining Journal.*

TWO NEW ELEMENTS?

Dr. Baskerville, whose position as professor of chemistry at a prominent Southern university entitles his utterances to every consideration, recently announced that he had discovered what are probably two new elements associated with thorium, both of them radio-active. The two new substances have been christened caroliuium and berzelium. Samples of the substances isolated by Professor Baskerville have been sent to Sir William Crookes, who will doubtless confirm or disaffirm the assertion that they are new elements.

The importance of the discovery, if it should ultimately appear that the two new substances are elements, can hardly be overestimated; for the number of radio-active substances is now increased to about six. Sir William Ramsay is reported as having every confidence in Dr. Baskerville's announcement.—*Scientific American.*

Mechanical and Engineering Section.

Stated Meeting, held Thursday, May 12, 1904.

Experimental Work with Solid Emery Wheels.

By T. Dunkin Paret.

The commercial literature of mechanical goods has steadily improved. The improvement of the literature has probably been as great as that of the goods. Each year catalogues and advertisements have become more precise. They fairly bristle with tabulations and data. The automobile, gasoline launch, dynamo, turbine wheel, steam boiler, engine and 12,000-ton armor-clad are all exploited in delicate half-tones, on expensive paper; but side by side with the pictured show goes a guaranteed statement as to actual performance.

To this improvement the literature of the solid emery wheel is an exception. That literature swells with adjectives and generalities, and is over-weighted with broad, unspecific claims. Every emery-wheel maker in America makes "the best wheel." These wheels are sharp, cool and free-cutting, and generate no heat. They work equally well wet or dry. Some of them are composed entirely of mineral substances, so that everything cuts. Some of them are noted for open texture—you can even blow through them! They are nearly all noted for their durability.

All wheels being thus equalized in the advertisements, the buyer thinks one wheel as good as another, and either changes carelessly from one make to another, or guides his choice by the biggest discount.

The presumptous demander of definite data would certainly receive none. It is a singular fact that the buyer rarely seeks data. Occasionally a very green one asks how long a wheel ought to last. As he does not give the size of the wheel, nor the speed he intends to use, nor the pressure he means to apply, nor the metal he desires to grind, nor

the number of hours per day the wheel will run, it is manifestly impossible to answer his question.

On the one side the buyer has no guarantee nor definite data as to the performance of the wheel he buys, and, on the other side, the seller has no certainty as to the conditions under which his wheel will be used. Thus results recrimination. The buyer complains that his wheel is a disappointment and that one wheel is as bad as another. The maker retorts that no wheel can be expected to do well which is run under improper conditions in defiance of the maker's rules.

In this state of affairs several questions clamor for answer. Is one wheel as good as another? Is it safe to buy at random and to place equal value on all wheels? Is there any method by which the buyer can ascertain the relative value of wheels? Is there any reason why emery wheel catalogues and advertisements should not supply definite data?

A very recent experience throws some light on the question as to what chance an inexperienced buyer would have in his first attempt to buy a good emery wheel. As preliminary to experimental work by the writer of this paper, five emery wheels were ordered directly from five different manufacturers. The factories which supplied these wheels were all long-established ones, popular and of excellent repute. The orders indicated the number of emery, and called for the wheels best suited to general machine-shop work, for hand-grinding on cast iron.

Tested under conditions practically identical, the results were so widely different as to demonstrate beyond doubt that there was only one chance in five of getting a good wheel. One wheel ground off $12\frac{50}{100}$ ounces of cast iron in 4 minutes, but lost $16\frac{18}{100}$ ounces of its own material in so doing. A second removed $13\frac{25}{100}$ in 4 minutes, with a loss of $15\frac{62}{100}$. A third removed only $6\frac{81}{100}$ in 4 minutes without apparent loss of wheel material. A fourth broke badly after only 40 seconds. A fifth removed $13\frac{81}{100}$ with a loss of only $1\frac{81}{100}$.

If an inexperienced man had bought these wheels in the

consecutive order here indicated, he might well have given up in disgust his search for a good wheel. The first two wheels were entirely too soft for this test, and lost about one-eighth of their available substance in 4 minutes. The third and fourth wheels were as much too hard for this test as the first and second were too soft. The fifth was "a good wheel." It removed a reasonable amount of metal with a minimum loss of wheel material.

The citation of these figures, however, is but a partial explanation. Though the great defect of emery-wheel literature is its lack of definite tabulations, it is a fact that mere numerical data are misleading. Such data must be supplemented by the oft-repeated observations and deductions of those practically familiar with emery wheels. It is not enough to say that the first two wheels were too soft. It must also be pointed out that at the end of 4 minutes each wheel was worn out of shape, and that, in consequence, the bar was being ground to irregular shape. It must also be shown that the tabulated loss of wheel material does not indicate the eventual sum. Great additional loss would accrue when the wheel was turned so as to have a square face, and still further loss would occur in the useless hub. Besides this great eventual loss of material, not indicated by the tabulations, there is a further loss due to the repeated turnings or truings of the wheel and the labor thereby incurred. Of great importance also is the fact that, at such rapid rate of wear, correct work could only be done for a few seconds at a time.

If the over-hard wheels were to be valued by the numerical data only, a great error would result. It is said of the third wheel that it removed $6\frac{81}{100}$ without apparent loss of wheel material. The truth was that at the end of 4 minutes this wheel weighed $\frac{12}{100}$ of an ounce more than at the beginning, notwithstanding the fact that its edges were badly broken. This gain was due to the metallic coating which flecked it heavily over.

No mere numerical table or chart of curves can be made to include the many and varied mitigating elements and collateral circumstances connected with an emery wheel

test. To estimate the value of this third wheel we should have to determine the real loss of wheel material as contrasted with the apparent loss. This loss would depend on the weight of the broken edges, and the weight removed in the numerous turnings necessitated by rapid and heavy metallic glazing. To still further complicate the problem, it must be pointed out that the tabulated metal removal is affixed to a 4-minute period. None but a critical experimenter will realize the fact that this wheel's best cut was at the start, and that metallic glazing is accompanied by a lessening product. The problem to be solved is as to what will be the average minute removal for a day's work if the average for 4 minutes is $1\frac{70}{100}$ ounces per minute. Then, again, the fact is to be considered that flying edges might destroy the sight, and that they clearly indicate a dangerous tendency.

The defects which characterized the third wheel were intensified in the fourth. This wheel broke badly at the end of 40 seconds and was very heavily coated with metal. This experiment (being restricted to 4-minute tests) affords no evidence as to product and wear under continued use. Such evidence can be supplied by reference to an older investigation.

Under date of September 9, 1891, Coleman Sellers, J. E. Denton and Alfred R. Wolff made a "Report on the Comparative Value of Fifteen Varieties of Solid Emery Wheels." This report states that eleven (out of fifteen) varieties were slow cutters, and it contains a striking paragraph as to the two varieties for which it claims pre-eminence. This paragraph reads as follows: "One striking feature characterized these two; that is, that in every series of trials these wheels increased in productive capacity, the average of the last cuts of all the series being greater than the average of all the first cuts. The thirteen other varieties all decreased in productive capacity, the average of the last cuts being less than the average of the first. Some of those which made a brilliant show at the start cut scarcely anything at the close."

This loss of productive capacity is largely due to that

metallic glaze which characterized wheels 3 and 4 in this later trial. This glaze, which is almost steadily cumulative, affects both the cutting capacity of the wheel and its safety. The wheel which glazes badly is likely to burst. In conducting some of these experiments at night, the progressive glazing became visible. When a wheel of this character first began to grind it was surrounded with a halo of brilliant, corruscating, white sparks. Through these a very narrow cherry-red line came slowly into sight, and this line grew and widened into a cherry-red ribbon. This ribbon indicated the increasing band of metallic glaze, which band, though formed of discontinuous blotches and flecks of adhering metal, appeared, at that speed, like a continuous ring. It was soon noticed that if this ring grew and widened rapidly the wheel broke or burst before the end of the test.

This fact has significant bearing on the question as to whether certain makes of wheels are inherently safe and other makes dangerous. It also demonstrates the fallacy of tests restricted entirely to speed. One such test has recently been made under circumstances which give it special prominence. There was (apparently) in Germany such general distrust of solid emery wheels that these wheels, either from custom or legislative restriction, were run at a speed too low for effective work. With the view of altering these conditions a series of trials was inaugurated by the Association of German Engineers, and carried out by Prof. M. Grübler, of the Technical High School, Dresden. His preliminary report was dated May, 1902. In these trials the solid emery wheels were run free, and the only real result was to determine the maximum bursting speed. Nevertheless, the wheels are classed (as to their binding material) as vegetable, mineral, chemical, unknown and animal. It seems evident that the wheel with the highest maximum bursting point was to be considered the strongest, and that the nature of its binding material was to be considered only with reference to its cohesive quality.

This German trial demonstrated the fact that nearly all the wheels could endure the standard American speed; but this fact had long been patent to American makers and

users of solid emery wheels. If solid emery wheels were to be run free, this trial would have some value; but wheels are intended for practical use, and their probable behavior under such use is the chief matter of inquiry.

The American trials reported in 1891 are eminently practical, as compared with this German one. The American investigators agreed as to the qualities which constitute "a good emery wheel," and these were stated to be: "Safety under the widest conditions of use and misuse; rapidity of cut; freedom of cut at moderate pressure; reasonable amounts of wheel loss and power consumption; evenness of wear; general staying quality, and reliability under the widest range of circumstances."

To demonstrate these qualities it was necessary to elaborate a process and to invent a machine. The report states that "This machine was so constructed that the wheel and work were brought in contact by definite and measurable pressure, without any obstacle being interposed to the free wear of either metal or wheel. The results approximated closely to those obtained by hand pressure, and yet were independent of all influence from the operators of the machine." These words were written many years ago, and they apply with still greater force to the more modern machine and process used in the experimental work which is the special subject of this paper.

The makers of the over-soft and over-hard wheels (1 to 4) might object that the machine and process which produced such opposite and unfavorable results were not suited to their wheels, and did not conform to that requirement of the order which specified that the wheels should be those best suited to general machine-shop work, for hand grinding. To this objection the answer is that while the machine and process are not identical with handwork, they assimilate closely to it. The characteristics of general hand grinding are intermittent contact between wheel and work at irregular intervals of time under pressure unknown and variable.

For this the new process substitutes intermittent contact at regular intervals under known and uniform pressure.

Before deciding as to this pressure the ordinary method of a skilled grinder was observed, and the deflection under pressure of the bar used to grind on was carefully noted. The same deflection being then reproduced by the attachment of weights to the bar, the actual pressure was obtained. Long experience, both previous and subsequent to this report, confirms the fact that it is an easy and customary thing in hand grinding to attain the pressure at which wheels 1 and 2 wore out with undue rapidity, and 3 and 4 glazed and broke.

If all makes failed at this pressure and under this process, it might justly be claimed that the test was not fair; but as wheel 5 stood the test, and as still other makes have stood it repeatedly, it seems fair to approve the one class and to condemn the other.

Wheel 5 removed $13\frac{81}{100}$ ounces of cast iron in 4 minutes with a loss in wheel material of only $1\frac{81}{100}$ ounces. These figures are suggestive, but neither figures nor charted curves would tell its true story. It must be also taken into account that this wheel had no broken edges, that its face remained square and true, and that it showed not the slightest adherence of metal. It would be a big jump from this 4-minute test to the conclusion that wheel 5 was a perfect wheel; but subsequent trials with this same wheel and unnumbered trials with wheels of the same make, and with others of similar quality, confirm the inference that wheel 5 is one of a class inherently sound and good, as contrasted with other classes, some of which are inherently dangerous and all defective.

It may be claimed that the wheels here classed as over-soft and over-hard are only proved so by their failure under this particular process and on this particular machine, and that at pressures adapted to them they would work to satisfaction. It is possibly true that, under lighter pressure, wheels 1 and 2 might have made a better showing, and that wheels 3 and 4 might not have broken so readily. Such necessities of careful adaptation do not characterize wheel 5 nor other wheels of similar general quality. Wide experience shows that such wheels are safe under the widest con-

ditions of use and misuse, and are reliable under the widest range of circumstances.

Attention is asked to the assumption of inherent safety and inherent danger. Is this assumption correct? The inferences from the preliminary German report are that the safety of a solid emery wheel depends on its ability to withstand the disrupting strain of centrifugal force and that the cohesive strength of its binding material is the all-important element. This report shows, however, that the minimum bursting point of the fifty-four wheels (of nineteen varieties) tested was at more than double the usual standard American speed, and that the average bursting point (in revolutions per minute) was at more than three times the customary American speed. The correct inference is that nearly all wheels have a wide margin of safety so far as speed and centrifugal force are concerned, and that the safety of a wheel in use demands other qualities than cohesiveness.

The ordinary observer is apt to infer freedom of cut from the open texture of a wheel and to argue that such a wheel will generate little heat. The commercial literature of the emery wheel perpetuates several erroneous ideas on this and other points. It suggests that gums, glues, cements, etc., are used in some makes as a binding material, and that these substances completely fill the interstices between the emery grains, thus creating a close instead of an open texture and interposing a non-cutting substance between the mineral grains. It is argued that if each of these grains is surrounded with a non-cutting substance, it cannot itself cut to advantage. The superiority of wheels entirely mineral is proclaimed, and a typically good wheel is said to be one in which mineral grains are so united at the corners as to leave plentiful and relatively large interstices.

The mere appearance of an open-texture wheel is attractive, but this appearance is delusive, as is also the theory concerning texture. Nothing save repeated experiments and long experience can demonstrate which make of wheel is inherently free-cutting and safe; and, when demonstrated, it is not easy to see why one make possesses good qualities

and the other lacks them. Experience and experiment do both demonstrate the fact that the best wheels are of close texture. It is possible that the pores of open-texture wheels may be too ready lodging places for dust and débris, and that heated metal, forced into such interstices, may mat and bed and cling, while, on compact wheels, it would fail to adhere. It must be noted, also, that vitrified and silicate wheels (all wheels, in fact, which are entirely mineral) are incombustible. On the other hand, wheels whose binding material is gum, glue or other organic matter are readily affected by heat, and as the interstitial matter chars and crumbles, fresh surfaces are steadily and persistently exposed.

It is a fact, therefore, demonstrated by countless experiments and long experience, that certain makes tend to fleck or flake over with adhering metal, and that this adherence lessens their productive capacity, and also makes them unsafe. Whether this is due to texture, to chemical composition or to their quality as conductors of heat, is uncertain.

One most important fact, not indicated by charts or tabulations, is that which concerns the proper cutting surface of a wheel. The acceptance of poor wheels and the condemnation of good ones is caused by a mistake on this subject. Every wheel, as sent out by its maker, has an unnatural artificial surface, and, as a rule, it is by this surface that the wheel is judged. A new wheel is offered for trial, and if it starts off with a rush, cutting rapidly and brilliantly, is accepted after the test of a few minutes. The rapid cut may be due, and often is, to the roughness of a hacked, dressed or artificially procured surface, and the wheel may steadily deteriorate or settle down to a slow cut. Another wheel may be too smooth, and make but a poor show at the first. The operator is likely to be impatient and condemn this wheel, yet it would almost surely increase in product after reasonable time and greatly surpass the execution of the brilliant first-minute cutter. It is a good rule, steadily advocated by one firm of wheel-makers and observed by very few operators, not to accept or condemn any wheel

until by actual work in grinding its diameter has been reduced at least $\frac{1}{4}$ of an inch.

In view of this fact it is a great error to use too frequently the emery wheel dresser, the diamond point or the hacking tool. A poor wheel which quickly flecks over with metal may require this; but such requirement, with its necessity for useless labor and its steady consumption of wheel material, is enough to condemn any wheel. A good wheel does not require it, and, every time that such a wheel is dressed, time and material are wasted and an artificial surface substituted for a natural one.

In order to lead up to recent experimental work it seems best to reproduce a few facts from the investigation reported on in 1891. In that test seventy-eight wheels were employed and fourteen of them burst. One hundred and ninety-three trials were begun and only 136 completed. The average metal removal per minute at a pressure of 112 pounds per square inch was 1·409 ounces. In calculating the loss of wheel material no account was taken of the wheels which burst, nor was the real loss of material correctly ascertained in the case of those wheels which glazed heavily. Fifty-seven trials were begun, which, from unstated causes, were not completed. As fourteen wheels burst, it follows that forty-three tests failed from other causes. These failures have a strong bearing on the question of staying power and general reliability. Sometimes these wheels wore out of true to such an extent that the bar could not be kept in proper contact. Sometimes they threw belts off the pulleys. From various causes the machine was stopped, the process brought to a standstill and valuable time wasted.

Comparison of the old and new trials demonstrates the fact that definite qualities are permanently attached to different makes. In the preliminary test of 1903 wheel 3 removed only $1\frac{70}{100}$ ounces per minute, while wheel 5 removed $3\frac{45}{100}$. In the test reported in 1891 the prototype of wheel 3 (a wheel of the same make) removed only $\frac{47}{100}$ per minute, while the fellow of wheel 5 removed $1\frac{92}{100}$. It cannot be chance which, at an interval of fifteen years, shows one make to be good and another bad.

Inasmuch as a valuable result of every investigation is that general experience which cannot be tabulated, the extent of the investigation is a matter of importance. Inferences, deductions and theories are of little value if they depend on a few observations. If the number of observations is great and the results correspond with those of other investigations, the inferences are correspondingly safe.

The investigation of 1903 and 1904 comprises 194 finished tests of 4 minutes each, or 776 distinct tests, and a certain number of incomplete tests which also throw light on the subject. The wheels used came from seven different makers, and were forty-eight in number, of thirty distinct varieties. The average diameter of these wheels was about $9\frac{1}{2}$ inches, and the average revolutions about 2,250. The metal consisted of bars $\frac{3}{4}$ of an inch wide and $\frac{1}{2}$ inch thick. Tests were made at various pressures, but those at 112 pounds per square inch are considered the most instructive. At this pressure 244 1-minute tests were made on cast iron, thirty-six wheels being used, of twenty-six classes or varieties. The metal removal averaged $2\frac{67}{100}$ ounces per minute, and for each ounce of metal ground off $\frac{17}{100}$ of an ounce of wheel material was consumed.

Towards the close of this investigation three classes were selected, as being among the fastest cutters, and subjected to special trials. At 80 pounds pressure per square inch, the average minute removal of cast iron was $3\frac{9}{100}$ ounces, and the wheel loss $\frac{29}{100}$. At 110 pounds the metal removal increased to $5\frac{38}{100}$, with a wheel loss of $\frac{67}{100}$. These cuts illustrate what may reasonably be expected from a good wheel.

This investigation was expected to cover wrought iron and tool steel, but so much time was employed on cast iron that equal series of trials could not be completed. Some deductions can be drawn from the unequal series, but the averages are not so trustworthy as in equal series. It may be stated, in a general way, that wrought iron and tool steel are ground off much more slowly than cast iron, and that they are more destructive to the wheel. In fifty-two

1-minute tests on wrought iron the minute removal averaged $1\frac{3}{100}$ ounces, while for each ounce of metal removed $1\frac{8}{100}$ of wheel material was consumed.

An attempt has been made to arrive at the cost of grinding both on cast and wrought iron, and also at the cost of filing, but it must be remembered that the conclusions which are drawn from very unequal series are not altogether sound. In arriving at these costs, a wheel 10 x 1 is assumed to weigh $7\frac{3}{4}$ pounds and to cost $1.65—that is, 75 per cent. discount on a list price of $6.60. Labor is calculated at the rate of $1.75 for a day of ten hours. No allowance is made for power. Under these conditions, and counting only the cost of wheel material and the actual time of grinding, at a pressure of 112 pounds, it costs $5\frac{26}{100}$ cents to grind 1 pound of cast iron and $27\frac{53}{100}$ cents for the same quantity of wrought. This cost, so far as it refers to cast iron, is derived from the 244 minutes test of thirty-six wheels. It is interesting to note that the few trials of specially fast cutters show a diminished cost. This diminished cost (on cast iron) is almost the same at 80 and 110 pounds. At 110 pounds the cost of material is greater than at 80 pounds, while the cost of labor is less. At 80 pounds the total cost is $3\frac{40}{100}$ cents per pound; at 110 it is $3\frac{52}{100}$.

A few tests were made with the file on bars furnished for the grinding test, three different machinists being timed. These gave a cost per pound of $29\frac{90}{100}$ cents for cast iron and $74\frac{75}{100}$ cents for wrought. The minute removal by the file for cast iron was $\frac{15}{100}$ of 1 ounce; for wrought iron $\frac{6}{100}$.

To throw light on this recent investigation and on its relations to practical work, the data of a much older test are here reproduced. The new test machine and process will be objected to by some as not corresponding to shop practice. These same objectors would probably condemn a hand-test, because the personal factor throws doubt upon it. It is interesting, however, to see how far old tests, made by hand under very different conditions, compare with the modern ones.

The old tests (made under the supervision of the writer of this paper) were described in *The Railroad Gazette* of May

27, 1887. The grinding was done with a wheel 14 x 2, cast-iron bars 3 feet long, 2 inches wide and $\frac{1}{2}$ inch thick being employed. The product decided upon as a fair average was $4\frac{13}{100}$ ounces per minute at a cost of $5\frac{80}{100}$ cents per pound. This cost was based on the much higher prices then asked for emery wheels and on a higher rate of wages. Calculated on the same basis as that of the recent test, the cost would be $2\frac{57}{100}$ cents per pound. This cost is still lower than that due to the use (in recent test) of a free-cutting wheel at 110 pounds pressure.

While it is not entirely safe to draw conclusions from tests so widely different, it may be pointed out that, in the recent test, the metal surface in contact with emery wheel measured only $\frac{3}{4}$ inch by $\frac{1}{2}$ inch, while in the old tests (hand grinding) the area of contact was 2 inches by $\frac{1}{2}$ inch. While hand tests (as matters of comparison) are unsatisfactory, because the pressure is an unknown quantity, it is quite certain that 110 pounds per square inch can easily be attained by the use of a 3-foot bar. Another unknown factor in this particular problem is the difference in product due to difference in diameter of emery wheel. It is claimed in a general way by some that wheels of large diameter are better grinders than those of less diameter. Data on this point seem to be entirely lacking, though their value would be great. It is possible that the decreased cost shown in the hand tests may be due to the use of a wheel of large diameter.

In this same old hand test the cost of grinding wrought iron is figured at $21\frac{20}{100}$ cents per pound. The cost of filing cast iron is put at $35\frac{90}{100}$ and of wrought iron at 75 cents.

As bearing on the rate of product, it may be stated that the minute product of the fastest cutter was 7 ounces, and of the slowest cutter only $1\frac{25}{100}$ ounces.

One striking fact is brought out by these old tests, and this is that the emery wheel (even in hand grinding) maintains its rate of product far better than the file does. In a half-hour test (by wheel) the minute average was only 16 per cent. less than the best cut made. By file test the minute average was 49 per cent. less than the best cut.

While part of this decrease is due in both cases to fatigue of the laborer, it is due in greater part to steady deterioration in the cutting power of the file; and the longer the test the more unfavorable would be the results of the file.

Another comparison between wheel and file may be referred to with advantage. In *The Iron Trade Review* of March 28, 1889, the comparative products of wheel and file are set forth pictorially. The pictures show the exact size and shape of cuts made in cast iron and saw steel by wheel and file. The data prove that, under ordinary shop conditions, the wheel ground (on saw steel) $16\frac{1}{2}$ times as much as could be filed off in the same time, and, under far better conditions, 126 times as much. The steel used was No. 9 wire gauge (American standard); that is to say, about $\frac{1}{8}$ inch scant, or 3 millimeters thick. In 30 seconds the wheel ground a slot $\frac{15}{16}$ of an inch wide by $4\frac{1}{4}$ inches deep. The slot made by a new file in 60 seconds was only $\frac{1}{2}$ inch wide by $\frac{1}{8}$ inch deep.

It is a difficult task to draw correct deductions from numerical data listened to, as this paper is, and even the expert may find cause for long study in the printed tabulations. These details barely suggest certain facts which the experimenter appreciates in part and around which there are many doubts only to be cleared up by much more thorough investigation.

Under all these investigations is hidden the as yet unexplained factor of heat. Heat is the great underlying, uncalculated and often unsuspected factor in emery wheel accidents and also in emery wheel product. In old times wheels were occasionally made so lacking in cohesiveness (so rotten) that they flew to pieces merely from the centrifugal strain. Such cases are extremely rare nowadays. In some cases wheels of proper coherence are burst by the sudden application of excessive pressure, as when a piece of metal gets jammed between the wheel and the machine rest, or as when a strong man applies the leverage of a long bar. Occasionally, wheels are unsafe owing to some crack undiscovered at the time of shipment, or produced afterwards during transit or use. The main cause, however, of bursting wheels is heat.

Just how heat operates is somewhat of a mystery. The conclusion seems natural that wheels which are poor conductors of heat are the most unsafe. In such wheels the heat created by friction at the circumference works slowly towards the center, and the outer rim expands with speed disproportioned to that of the center. Such expansion might result in cracks transverse to the face and other cracks radiating from face to center. As a matter of observation, the wheels which are unsafe are those whose substance conducts heat easily, and which quickly get hot all through. Such wheels throw off broken edges and irregular chunks, and burst entirely without any definite system of cracks.

It follows from this that wheels entirely mineral are not, as a class, so safe as those in which the mineral grains are surrounded and separated by gums, glue and other organic matter.

The adhesion of metal to the surface of the wheel is also, to some extent, an effect of heat. It may be that wheels with this defect overheat and soften the metal, or the adhesion may be due either to the chemical constitution of the wheel or its physical structure. It is a clearly ascertained fact that free-cutting wheels are not characterized by such adhesion, and that slow-cutting wheels are. It is also evident that as the metal increases in heat the cut (or product) decreases. It is seldom that the end of a $\frac{3}{4}$ x $\frac{1}{2}$ cast-iron bar is much reddened by the grinding of a free-cutting wheel, and the edges of the bar are generally clean-cut. Under the same conditions wrought iron gets red-hot for a considerable distance and flattens out and bends over at the edges.

Many years ago an experimental test machine was built in which the metal was forced against the wheel by a continuous screw feed. As the bar elongated with heat, the pressure increased, and with increased pressure increased heat was generated. Under these conditions the bar became intensely hot and red, and the wheel almost ceased to cut.

Complicated with these questions of heat is the subject of contact area and clearance. The ideal conditions of grinding are those in which wheel and work come in contact on a narrow line. A thin edge of saw steel will be

ground rapidly and effectively if pressed against the face of a wheel, while a large flat surface shows little product if pressed against the side. While this is partially due to the vastly greater pressure per square inch in the case of the thin edge, it is also due to the lower heat which results from proper clearance. In the case of the thin edge all débris of wheel and metal fly instantly away, each grain removing its quota of heat. In the case of two large flat surfaces rubbing together the débris is retained (with its included heat) and is bruised into the interstices of the wheel, interfering with its cut. For this reason it is a radical mistake to fit wheel and work in such way that large surfaces are in contact. Cone wheels exactly fitted to corresponding interior metal surfaces (axle-skeins, for instance) are a mistake. So would large, curved grinding blocks be if applied like brake-shoes to the curved face of a car wheel.

The tread of car wheels has long been ground in a practical way with an ordinary disc-shaped emery wheel, the curved exteriors merely touching on a narrow line and affording excellent clearance for wheel and metal débris. For this process, some years ago, was substituted a grinder, in which cup-shaped wheels were used. When the writer of this paper saw that machine in operation, a keg of grain emery stood close at hand, and the operator from time to time dropped some of it between the car wheel and the emery wheel. Questions and further examination brought out the fact that flecks of metal adhered periodically to the emery wheel, and that no proper work could be done until these were removed by the use of the loose grain emery. It was stated that the formation of a single fleck could be heard at the most distant corner of the shop, and this proved true. It was also stated that, when the rims or cutting edges of these wheels were pretty well worn down, such rims were removed entirely, and the wheels transformed into ordinary disc wheels. In this altered form, when the convex exterior of the grinding matter was used instead of its flat side, the wheels did good work and no metal adhered to them.

In the absence of verified data as to the relative cutting

capacity of small and large wheels, it is well to point out the manner in which circumference and mass modify the effects of frictional heat. The circumference of a 6-inch wheel is about 19 inches; that of a 36-inch wheel about 113 inches. A wheel 6 x 1 contains about 28 cubic inches; a wheel 36 x 4 about 4,000 cubic inches. The standard speed of a 6-inch wheel is 3,600 revolutions per minute; that of a 36-inch wheel 611 revolutions. If a bar $\frac{3}{4} \times \frac{1}{2}$ inch is ground on these wheels the heat problem will be different in each case. At the first moment, when bar and wheel come in contact at heavy pressure, intense heat will be developed. In the 6-inch wheel this spot (each and every point of contact) will be heated 3,600 times in a minute, while in the 36-inch wheel it will be heated only 611 times. Though both wheels travel at the same surface speed the circumference of the 36-inch wheel is so much greater that it has about six times greater ability to cool. The greater area of its surface causes greater radiation and loss of heat, while that which remains has about 4,000 cubic inches of matter to diffuse itself through, instead of the 28 inches allotted to the 6-inch wheel. If, therefore, frictional heat is an undesirable thing, the advantage of large wheels becomes evident.

There is *apparently* one clear deduction from these facts, and this is that water should be used to prevent the injurious effects of heat. Nothing can be more erroneous than this deduction, and nothing has done more to retard the proper development of grinding processes. The use of water on solid emery wheels is a survival of the old Sheffield methods, in which huge grindstones are run in a stream of water in which the workman straddles a board that presses his work against the stone in which the heaviest man is the best grinder.

The use of water has been urged indiscriminately as an excuse for an increased variety of grinding machines, and, in times past, as a method of using emery wheels too weak and poor to be used dry. It is not an uncommon thing to read, in commercial literature, that certain wheels can be used equally well wet or dry. In justice to the getters-up

of such vague assertions, it is assumed here that they are not intended to imply equal products by the wet and dry processes. It is to be feared, however, that the long-continued and oft-repeated assertion of this generality has created a false impression.

In opposition to any such view, it should be stated in the strongest way that water is a lubricant. Exact data on this subject seem to be almost entirely lacking, but the only ones known to the writer (and procured under his supervision) are now given. Seven different makes were tried under conditions identical except as to the fact that in one series the wheels were used dry and in the other series wet. Sixteen consecutive, intermittent cuts were made by each wheel in each series of trials, the speed being about 1 mile per minute, the pressure about 112 pounds per square inch and the material ground cast iron. The total product of five of these wheels under the dry process was $186\frac{12}{16}$ ounces, while under the wet it fell off to $24\frac{13}{16}$. Two (out of the seven) wheels gave a larger product under the wet process than under the dry, but this result confirms the facts previously adduced as to over-hard wheels and the lessened product due to metallic adhesion. In 32 minutes these two wheels ground off, under the dry process, $2\frac{2}{16}$ ounces and, under the wet process, $10\frac{2}{16}$. It seems evident that in this case the use of water lessened the metallic adhesion.

The fact is that water is only necessary to protect metal from the effects of heat. Where there is danger of warping in some article held while cold under the stress of undue tension, or where some desired temper is altered, water can be advantageously employed, but its indiscriminate use (on tools, for instance) encourages careless methods. The dry process carries on a steady educational work, the grinder acquiring increased delicacy of touch and greater knowledge as to the contraction, expansion, density, stress and temper of metals.

It is a too common assumption that tools cannot properly be sharpened on a dry wheel, yet experienced operators can produce any desired temper by the skillful use of the dry process. The tempering furnace has been (in at least one

instance) abandoned for a tempering wheel, and saws have been given an increased durability by the special hardness due to careful use of a dry wheel.

One final tabulation is now given to substantiate these statements. The advantages of intermittent pressure, as affecting the heat problem, are very evident, and the disadvantages of grinding with a flat surface have been pointed out. The facts that high speed is connected with a free cut, and that a free cut generates the least heat, are well understood. It will, therefore, be readily perceived that if a knife edge is ground on the flat surface of a wheel at half speed, under an unyielding screw feed, all the elements of temper destruction are present. Nevertheless, a 2-foot planer-knife, with bevel $\frac{13}{16}$ of an inch wide, has been successfully ground on an automatic knife-grinding machine with a dry wheel, under the disadvantageous conditions just stated. The record states that such grinding did not blue the knife, which remained cool enough to handle. If a machine can do this, what will not the sensitive and delicate hand of a skilled workman accomplish?

The art of grinding is still in its infancy. There is great need of long-continued, careful investigation, verified statistics and sound deductions before wheel-makers can learn what to claim and wheel-users know what to demand. At present the solid emery wheel is a greatly abused tool, and the emery wheel industry is in undeserved ill-repute.

The emery wheel will accomplish all that its warmest advocates claim if it is used with average care and skill under conditions perfectly reasonable and easily established.

APPENDIX.

SUNDRY ABSTRACTS.

Abstract No. 1 relates to tests made by T. Dunkin Paret, November 17, 1903, to January 29, 1904:

NO. 1.

Metal ground, cast iron in bars, inches	¾ x ½
Approximate pressure in pounds per square inch	112

Quantity of emery wheels used	36
Classes " " " "	26
Number of 1-minute tests	244
Average number of revolutions per minute	2,220
" diameter of wheels in inches	$9\frac{1}{2}$
" metal removal per minute in ounces	2·678
Maximum " " " " " "	4·68
Minimum " " " " " "	1·
Average wheel loss per ounce of metal removal	·165

Abstract No. 2 relates to tests made by T. Dunkin Paret, February 5, 1904, with specially selected fast-cutting emery wheels:

No. 2.

Metal ground, champion tool steel in bars, inches	$\frac{3}{4}$ x $\frac{1}{2}$	$\frac{3}{4}$ x $\frac{1}{2}$
Approximate pressure in pounds per square inch	80	110
Quantity of emery wheels used	2	2
Classes " " " "	2	2
Number of 1-minute tests	8	8
Average number of revolutions per minute	2,212	2,257
" diameter of emery wheels in inches	$9\frac{50}{64}$	$9\frac{22}{64}$
" metal removal per minute in ounces	·63	3·05
Maximum " " " " " "	·93	4·31
Minimum " " " " " "	·31	·75
Average wheel loss per ounce of metal removal	·17	·36

Abstract No. 3 relates to tests made by T. Dunkin Paret, February 2 and 5, 1904, with specially selected fast-cutting emery wheels:

No. 3.

Metal ground, cast iron in bars, inches	$\frac{3}{4}$ x $\frac{1}{2}$	$\frac{3}{4}$ x $\frac{1}{2}$
Approximate pressure in pounds per square inch	80	110
Quantity of emery wheels used	3	3
Classes " " " "	3	3
Number of 1-minute tests	12	12
Average number of revolutions per minute	2,233	2,263
" diameter of emery wheels in inches	$10\frac{2}{64}$	$10\frac{2}{64}$
" metal removal per minute in ounces	3·09	5·38
Maximum " " " " " "	4 56	7·12
Minimum " " " " " "	2·00	4·18
Average wheel loss per ounce of metal removal	·094	·125

Abstract No. 4 relates to tests made by T. Dunkin Paret, December 8, 1903:

No. 4.

	Total Number of Minutes.	Total Metal Removal in Ounces.	Minute Average of Metal Removal in Ounces.	Total Loss of Wheel Material in Ounces.	Minute Average of Wheel Loss.	Size of Bar, Cast Iron.	Diameter of Wheel.	Pressure per Square Inch.	Revolutions per Minute.
1	4	12·50	3·12	16·18	4·04	¾ x ½	$10\frac{10}{32}$	112	2280
2	4	13·25	1·31	15·62	3·90	"	$10\frac{3}{32}$	"	2260
3	4	6·81	1·70	+1·25	—	"	$10\frac{3}{32}$	"	2270
4	40 sec.*	—	—	—	—	"	$10\frac{3}{32}$	"	2270
5	4	13·81	3·45	1·81	·45	"	$10\frac{2}{32}$	"	2280

*Broke badly in 40 seconds.

No. 5a.

No.	Revolutions per minute when bursting occurred.	Nature of Binding Material.	Origin.	No.	Strength in kilos and decimals of same.	Nature of Binding Material.	Origin.
1	4,063	Vegetable	European	1	251·3	Vegetable	European, A.
2	3,967	"	"	2	238·8	"	" A.
3	3,770	Mineral	"	3	212·9	"	" A.
4	3,737	Not Stated	"	4	201·4	Unknown	" A.
5	3,727	Vegetable	"	5	198·6	Vegetable	" A.
6	3,647	Animal	Tanite	6	190·5	Animal	Tanite, A.
7	3,643	Vegetable	European	7	184·2	Vegetable	European, A.
8	3,493	"	"	8	182·7	Mineral	" A.
9	3,307	Mineral	"	9	155·4	"	" A.
10	3,237	"	"	10	153·0	"	" A.
11	3,177	Chemical	"	11	140·4	Vegetable	" A.
12	3,040	Vegetable	"	12	134·2	Mineral	" A.
13	2,953	Chemical	"	13	125·8	Chemical	" A.
14	2,940	Mineral	"	14	123·4	Mineral	" A.
15	2,840	Chemical	"	15	108·3	Chemical	" A.
16	2,807	Mineral	"	16	96·8	Unknown	Safety, B.
17	2,760	Not Stated	Safety	17	95·7	Chemical	Norton, A.
18	2,680	Chemical	Norton	18	88·2	"	European, A.
19	2,615	"	European	19	73·9	"	" C.

A. A set of three wheels.
B. One wheel.
C. A set of two wheels.

Wheels were called for in sets of three, each set to be of exactly the same binding material.

Abstracts Nos. 5a and 5b relate to preliminary report of Prof. M. Grübler, of the Technical High School, Dresden, Germany, concerning tests made by instruction of the Association of German Engineers. Report dated May, 1902:

No. 5b.

Number of wheels tested	54
" complete sets tested	17
" incomplete sets tested	2
Origin of wheels, European	47
" " American	7
Approximate size of wheels, in millimeters	500 x 50
" " " in inches	20 x 2
Ordinary standard working speed, revolutions per minute,	1,080
Maximum weight of one wheel, in kilos	39·95
Minimum " " "	20·01
Maximum circumferential velocity per second, in meters	110·44
Minimum " " " "	64·72
Maximum bursting point, in revolutions per minute	4,210
Minimum " " " "	2,520
Average " " " "	3,312
Maximum strength in kilos	251·3
Minimum " "	73·9
Average " "	159·1
Binding material of wheels, vegetable	18
" " " mineral	15
" " " chemical	14
" " " unknown	4
" " " animal	3

Abstract No. 6 relates to the tests mentioned in the "Report by Coleman Sellers, J. E. Denton and Alfred R. Wolff on the comparative value of fifteen varieties of Solid Emery Wheels." Report dated New York, September 9, 1891:

No. 6.

Number of wheels tested	78
" " burst	14
" trials attempted	193
" " completed	136
Average metal removed per minute, in ounces	2·108
" " " " " at 112 lbs. per sq. in.	1·409
" " " " " 266⅔ " "	5·130
" loss of wheel material per minute (A)	·590
" initial cut per minute	1·955

Average final cut per minute . . . . 1·264
" maximum " " . . . . 5·662
" minimum " " . . . . ·118

In this computation the loss due to burst wheels is not considered, only the frictional wear being taken into account.

These tests were made upon bars of cast iron, $\frac{3}{4}$ x $\frac{1}{2}$ inch.

TABLE A.

Half-hour tests on brass, cast iron, wrought iron and hardened saw steel, with solid emery wheel, file, and hammer and cold chisel.

Weight of metal removed by	Brass.		Cast Iron.		Wrought Iron.		Saw Steel.	
	lbs.	*ozs.*	*lbs.*	*ozs.*	*lbs.*	*ozs.*	*lbs.*	*ozs.*
Emery wheel	17	0	7	12	2	8	3	7
File	0	8	0	5¾	0	2¾	0	1
Hammer and cold chisel . .	1	4½	2	5½	0	10½	0	1½

In obtaining the results tabulated above the same emery wheel was used on all the metals by the same man.

TABLE B.

Cost per pound of removing or wearing away metals, as based upon Table A.

	Brass.	Cast Iron.	Wrought Iron.	Saw Steel.
	cents.	*cents.*	*cents.*	*cents.*
Emery wheel	1·8	5·8	21·2	28·9
File	25·8	35·9	75·	206·4
Hammer and cold chisel . .	10·1	5·5	19·6	137·6

The cost table given above was arrived at as explained here. A uniform rate of \$2.50 per day of ten hours was fixed for grinder, filer and chipper, and 3 cents per ounce was fixed as the net cost of an emery wheel. A solid wheel 14 inches in diameter and 2 inches thick (the size adopted in all the trials), weighs about 30 pounds, and is priced in some lists at \$19.70. A discount of 33⅓ per cent. makes the net cost \$13.13, or 2¾ cents per ounce.

TABLE C.

Half-hour tests on brass, cast iron, wrought iron and hardened saw steel, with solid emery wheel and file.

	Brass.		Cast Iron.		Wrought Iron.		Saw Steel.	
	lbs.	*ozs.*	*lbs.*	*ozs.*	*lbs.*	*ozs.*	*lbs.*	*ozs.*
Weight of metal removed in one-half hour's grinding . .	17	0	7	12	2	8	3	7
Weight of metal removed in one-half hour by file	0	8	0	5¾	0	2¾	0	1
Weight of emery wheel removed in one-half hour's grinding	0	6½	0	11	0	13½	1	13

AUSTRALIAN OPALS.

The finest opals formerly came from Hungary, Mexico and Honduras, where they occur in igneous rocks. Australia is now the chief source of production, although the rich opal fields of White Cliffs, New South Wales, were only discovered by a mere accident in 1889. In 1902 the opals found in New South Wales were valued at $700,000 in all.

CYANIDE OF CACODYL.

Prussic acid has been considered to be the most deadly poison extant. Mr. Lascelles Scott, of Little Ilford, England, however, has now discovered a far more deadly poison—the substance scientifically known as di-methylarsine cyanide, or more familiarly as cyanide of cacodyl. Three grains of this substance diffused in a room full of people would kill all present, so powerful is it. So deadly is this poison that it is highly dangerous to handle it. It is a white powder melting at 33° and boiling at 140°. When exposed to the air it emits a slight vapor, to inhale which is death. Mr. Lascelles Scott has experienced the deadly nature of this poison, for while he was assisting Sir B. W. Richardson in the compilation of his work, "On the Causes of the Coagulation of the Blood," he tried its effect upon animals. One millionth part of cyanide of cacodyl in the atmosphere of an air-tight cage killed a dog almost instantaneously, and then its power was by no means exhausted, for a second, third and fourth dog placed in the same cage, instantaneously died from the effect of that single infinitesimal dose. Although so little of the properties of this poison are known, it was first made many years ago. Cadet, the famous French chemist, by combining acetate of potassium with white arsenic, produced a fuming liquid which, although he did not know it, was oxide of cacodyl. The German chemist Bunsen combined this with cyanogen, a radical of prussic acid, and made cyanide of cacodyl, the formula of which is $AsMe_2Cy$.—*Scientific American.*

Mechanical and Engineering Section.

Stated Meeting, held Thursday, March 24, 1904.

The Execution of Architectural Design.

By John McArthur Harris, M.A.,
Member of the American Institute of Architects.

(*Concluded from p. 74.*)

Some years ago a contractor overthrew an adjoining building. He was digging the cellar for the building he was to erect, and promptly failed. It was rumored that he had been paid no money for work up to that time, and that he had given no bond. The loss to the adjoining property was greater than the amount of work done by the contractor, so that the owner, without having spent a cent was in a position to lose thousands of dollars. I do not know what was the result of the catastrophe—that is, who bore the loss; but I do know that the danger of loss on the part of the owner could have been avoided if the bond had been promptly executed.

Contractors are usually required to keep buildings in course of erection insured from loss by fire and to assign the policies to the owner as his interest may appear. In case of a fire, contractor and bondsman together might not be able to bear the loss. Hence the identification with them for this emergency of the Fire Insurance Company.

Another security that is afforded the owner arises from the fact that it is customary to pay the contractor only a portion of the value of the work done from time to time until the work is completed. These payments are made on what is known as architect's certificates, which are simply vouchers that the contractor is entitled to a certain amount of money. This amount is usually arrived at by estimating the value of the work at stated intervals, and retaining a certain percentage, as stated above. The importance of the certificates arises from the fact that they are the basis of

payment recognized by the contract. And if the owner does not honor them, or pays without waiting for them to be issued, he lays himself open to loss in more ways than one. He may lose his contractor or his bondsmen, or he may have mechanics' liens filed on his building—provisions of the contract notwithstanding, because he has violated that contract.

The mechanics' lien is one of the strange things of the building business, and I think the law-makers have recognized the anomaly, because they have provided protection against it.

If the contractor fails to pay any of his employees, that employee can file a lien or claim on the building, and the owner must satisfy it, even though he has already paid the contractor for this very work.

To avoid this possible double payment on the part of the owner, the law of Pennsylvania provides:

WAIVER OF RIGHT TO FILE A CLAIM.

"SECTION 15. The right to file a claim may be waived by agreement between the claimant and the party with whom he contracts, or by any conduct which operates to equitably estop the claimant. If the legal effect of the contract between the owner and the contractor is that no claim shall be filed by anyone, such provision shall be binding; but the only admissible evidence thereof as against a sub-contractor shall be proof of actual notice thereof to him before any labor or materials furnished by him, or proof that a duly written and signed contract to that effect has been filed in the office of the prothonotary of the Court of Common Pleas of the county or counties where the structure or other improvement is situate prior to the commencement of the work upon the ground, or within ten days after the execution of the principal contract, or not less than ten days prior to the contract with the claimant. The only admissible evidence that such a provision has, notwithstanding its filing, been waived in favor of the claimant, shall be a written agreement to that effect signed by all those who, under the contract, are interested antagonistically to the

claimant's allegation. The giving of credit or the receiving of collateral security shall not operate to waive the right to file a claim, but shall delay voluntary proceedings thereon by the claimant until the time of credit shall have expired. A release signed by the claimant shall not operate as a waiver of the right to file a claim for labor or materials subsequently furnished unless it shall appear thereby that such was the express intent of the party signing the same; but such release shall be so construed as to fully carry out that intent."

The idea of this law is that persons who would have the right to lien may find out when payments are to be made and protect themselves at that time. Now if the owner makes his payments irregularly he takes away from the mechanic this protection and so gives him a right to protect himself by putting a lien on the building which the contract stipulates against. This is only one of the many illustrations that constantly arise of the necessity of:

(1) Having the contract fully expressed.

(2) Having it literally carried out.

It is the custom, before making a final payment and closing a contract, to have the contractor furnish a release of liens, which is simply a statement signed by all who would have the right to lien that they waive this right. This release will be required until the Supreme Court passes fully on the Act of June 4, 1901, quoted above, when it will become unnecessary.

The last instrument we have to deal with to-night is the guarantees. By this I mean certain guarantees that require time for their fulfilment, and unless satisfied in some way would keep open the contract longer than may be expedient. It sometimes happens that under a contract the contractor guarantees the working of apparatus furnished by a subcontractor—and at the completion of the rest of his obligations desires to terminate the responsibility he is under. This is often done by forming new contracts directly between the interested parties, and if the security is good the practice is not objectionable.

We have now reviewed together this somewhat extensive

field. I have named the parties who are interested in the carrying out of the design, and I have described in a very limited way the instruments that held them together, but we have still one matter to consider.

The owner, the architect and the contractor, these three are united in common purpose by a contract; but before this can take place there must be *selection*, first, of the architect; second, of the contractor.

How is this to be done?

The architects of the United States have a recognized organization which declared in its standard of practice:

"That the best results were to be obtained by an owner selecting his architect rather than by competition."

This practice is unobjectionable because the architect's charges are easily reckoned and readily compared so that he cannot overcharge.

The selection of a contractor is a more difficult problem, and many different methods are in use to determine the proper man to be selected.

Before I state some of these I would like to go over the condition of the contracting business as it exists to-day.

I spoke above of the change that has come over this business with reference to the manner of bonding the contractor. This is due, as I stated, to no ethical cause, but largely to the enormous financial load carried by the contractor.

By the introduction of the Bonding Company into the position of a partner, as it were, the contractor relieves the owner of anxiety with reference to the contractor's financial responsibility, but the practice has done more than this. It has brought into the competition many men who are not sound, but who hide behind the bonding companies when their standing is inquired into. The statement "I will give bond" is supposed to cover all questions of this nature.

Now, if the financial load has increased enormously, the practical load has fully kept pace with it. In the days of my grandfather the contractor could and often did know about all that went into the building. The few gas, water and other pipes, the furnaces, bricks, stone and mortar that

went into the building were comparatively easily carried in mind, and their installation followed.

Our builders cannot follow the huge contracts of to-day in the same manner. They sublet their work, of course, and they also sublet their obligations.

I have seen contracts between general and sub-contractors made so that everything the architect could ask the general contractor to do, the sub-contractor bound himself to execute. Reverse this and you have the rule that what the architect does not demand from the general contractor the latter will not demand from the sub-contractor. It would be a great thing for the building business if such contracts as this could be prevented. I know one large company in this city that has refused to sign an agreement of this nature, and that will make only independent contracts with general contractors.

I know of another company that overlooked the question of the financial responsibility of the general contractors with whom they made contracts, and depended almost entirely on liens to collect their money. This was an extreme case, and I use it as an illustration only to show how many forces are at work to relieve the general contractor of responsibility.

One of our leading contractors told me within six months that business was no longer conducted at the building but at the office.

I am not scolding. General contractors find as much fault as I do with the present system. I am simply stating conditions. And the condition I want to emphasize is this: That while the principal actor in the second period of design is the contractor, that is the general contractor, the standard of the work is no longer measured by the practical and financial ability of the contractor, but by that of his sub-contractors.

The usual method of selecting the contractor is to invite a limited number of contractors to bid, and to give the work to the lowest bidder.

The governmental way is to invite everybody that is in that particular line to bid, and to give the work to the lowest and best bidder.

It is customary in both methods to make a contractor submit a list of his sub-bidders, but the difficulties here are twofold. The contractor cannot be expected to change these sub-contractors for better ones without raising his price. He has accepted a poor sub-contractor to keep the price down and win the competition, and it is difficult to get the owner, who relies on architect and contractor to see that he gets good work, to pay more for good sub-contractors. It is dangerous, too, for an architect to dictate overmuch in the selection of sub-contractors, as it lessens the general contractor's moral responsibility.

Two other methods are:

(1) For the owner to pay all the bills and a percentage to the contractor. This is known as day's work, and is the poorest method of all. The contractor does not have to watch his force account, and the chances are he does not watch the job at all. He knows that the more the work costs the owner, the more the contractor will make. It reminds one of the old story of the Yankee and the Indian and the turkey.

(2) For the sub-contractors to be selected by competition from a selected list and the contract to be made for a lump sum, which shall include a fee for the general contractor, who shall be selected for practical fitness.

This way I like the best, provided a competent general contractor is selected, and provided the sub-contractors are not asked by the general contractor to take less than their original bids.

From the reports of sub-contractors, I judge it is a common practice for contractors to use sub-bids in making their own price, and to shave them when making their contracts with the sub-contractors. This concession on the part of the sub-contractor has to be met by the general contractor, and this vitiates his superintendence.

You have heard now the methods in vogue and you have listened to some of their limitations. I have not, in much discussion with architects and more with contractors, had any perfectly satisfactory method suggested.

Recently there have been signs of a new departure, new

only in the sense of its growing favor. This is, for the architect to make the contracts in place of the general contractor. This method has many objectionable features, but it has the great advantage that it enables the architect to deal directly with the men who are doing the work.

The owner finances the work by paying for the bond and by advancing money as the contract progresses. He superintends the work through his architect, who takes the moral responsibility for its success. The question arises: Are we to go forward in this direction towards the elimination of the general contractor from building contracts? It would be a brave man who would now predict it.

The great objection to the architect as a contractor is a moral one. It has always been considered better practice to have work superintended by a disinterested party, and it can be readily understood that it is better to have specifications drawn by parties who are disinterested, so that it may not be for the advantage of the profession to include general contracting.

The new Land Title Building, erected without a general contractor, may be only a monument, not a mile-stone, but the problem is one that must be faced and some day settled. I wish to excite your interest in it, and among yourselves and friends your discussion of it, so that as it becomes more urgent it may have had the study of earnest and able minds, for only by such study can its solution be along lines that will advance The Execution of Architectural Design.

TIN DEPOSITS OF THE YORK REGION, ALASKA.

Julius Cæsar's invasion of Britain marked many important beginnings in the history of the civilized world. It is said that one result of that epoch-making event was the revelation to the Roman world of tin mines in the hills of Cornwall. The popularity of that useful white metal began with its earliest importation to Rome, and has continued down to the present day; but the sources of the world's supply of tin have unfortunately not grown proportionately with our knowledge of the world. The mines of Cornwall are still productive, and like those of Bolivia and Saxony, furnish tin from vein deposits in the bed rock. But the greater part of the world's supply of tin is now obtained from alluvial deposits. Over three-quarters of it comes from alluvial deposits in the Malay Peninsula, otherwise known as the Straits

Settlements, and the islands of Banca and Billiton, off the north coast of Sumatra. Alluvial deposits in Australia also contribute to the total output. The world's production of tin in 1903 amounted to 92,536 long tons, of which the Straits furnished 54,797 tons, Banca 15,070 tons, Billiton 3,653 tons, Bolivia 9,500 tons, Cornwall 4,150 tons, and other countries the balance. Only 30 tons of this total amount were mined in the United States, and not more than 200 tons of metallic tin have ever been produced from ore mined in this country, although small amounts of tin have been found in no less than seventeen States and Territories. These facts lend unusual interest to the discovery of tin in our Alaskan possessions. A report entitled "The Tin Deposits of the York Region, Alaska," by Mr. Arthur J. Collier, has been recently published as Bulletin No. 229 by the United States Geological Survey in response to the demand for reliable information regarding the occurrences of tin noted in Alaska.

Placer tin was discovered in 1900 in the York region of Seward Peninsula, which is the land mass that projects from the west coast of Alaska to within 60 miles of Asia. Mr. Alfred H. Brooks, of the Survey, found in the placers of Anikovik River and Buhner Creek, one of its tributaries, some concentrates which proved to contain stream tin. Since that time an effort has been made to determine the extent and distribution of the stream tin and locate its source in bed rock. Though the occurrence of tin-bearing lodes had been previously reported, the first authentic discovery of this kind was made by Mr. Collier during the summer of 1903. Accompanied by Mr. F. L. Hess as field assistant, he visited Teller late in July, and there met a number of prospectors who had been searching for tin in the York region and who were anxious to have their specimens examined, since they were unable to identify tin ore. Among these specimens only one piece of tin ore was found, but it had been obtained in a new locality, and consisted of cassiterite crystals still in the matrix. During the following week Messrs. Collier and Hess visited Lost River, Buck Creek, and Cape Mountain, and located the tin deposits at those places. The results of their investigations are embodied in this bulletin, together with information derived from a study of specimens of tin ores and associated minerals recently brought from the York region by outside parties.

The geologic results of investigations made by members of the Survey will be published in detail at a later date, but brief descriptions of the general and economic geology of the region are included in this bulletin. Some valuable data concerning the means of transportation in this district and the fuel supply are given. The physical characteristics of tin ore and its associated minerals—tourmaline, garnet, rutile, wolframite, epidote, magnetite, fluorite and quartz—are described, and methods of assaying tin ore are discussed, among them a method elaborated by Mr. Eugene C. Sullivan, chemist of the Survey, by means of which minute traces of tin can be detected. A brief description of the better known tin deposits of the world is included in the bulletin in the hope that it may be of value to the prospector. The essential purpose of the bulletin is, indeed, to present such facts in regard to the occurrences and value of the metal as may be of assistance to those who are interested in the development of the field. The bulletin is printed for gratuitous distribution, and may be obtained on application to the Director of the United States Geological Survey, Washington, D. C.

ELECTRICAL SECTION.

Stated Meeting held Thursday, January 17, 1904.

The Storage Battery as Applied to Electric Railways.

By W. E. Winship.

Within the last few years there has been a decided change in the attitude generally taken as to the advantages and advisability of storage-battery installations. This is partly due to a better knowledge of the life which may reasonably be expected, and, to a minor extent, to improvements in construction and plates.

Storage batteries have shown their utility and economy especially in railway work, where current fluctuations are usually extreme.

Where the system, supplied from a single station, is large, and relatively small cars are operated, the instantaneous fluctuations will be a small percentage of the total load, and there would be no economy gained in removing them. The load in this case will very nearly follow the service supplied; *i. e.*, be steady and proportional to the number of cars, and the only effectual use of a storage-battery plant, outside the large element of reliability of operation secured by it, would be in regulating the load-factor on the generating units in service. There would probably be, even in this case, a considerable economy resulting in operating the generating units and boilers at their most efficient load. This fact and their importance as a reliability factor might determine their installation under the above conditions.

When large cars are operated, perhaps even in trains, and high accelerations are demanded, as in interurban work, the conditions are entirely different. The fluctuations are then enormous, frequently much in excess of 100 per cent. over the average load, and we very often find stations operating on a 50 per cent. load-factor in order that the maximum demand may be within the overload capacity of the generators.

As is well known, the efficiency of a steam engine is greatly reduced, and that of a generator also, to a smaller extent, when the average is much less than their rated load. With steam turbines this is true to a somewhat less degree, but there is still a great variation of steam consumption. The net efficiency of the engine-generator combination is the product of the efficiencies of the two, and suffers, therefore, more greatly than either singly. By using a storage battery, either with or without a booster, to absorb these fluctuations, it becomes possible to raise the load-factor by shutting down one or more engines and boilers, with a consequent decrease in coal consumption, reducing also such items as labor, oil, waste and repairs, thereby effecting a great economy. It is possible then to operate with less apparatus, and usually some saving may be made in initial power-house outlay, since an equivalent battery plant would cost somewhat less than the engines, boilers and generators it displaces.

As with all machines and contrivances, the efficiency of a storage battery plant is not perfect. On certain classes of work (viz., short cycles of charge and discharge) it is remarkably high. If the fluctuations are within the hour-rate of discharge of the battery, and are of short duration, it is very nearly 90 per cent. Tests published by Highfield,* covering a year's actual operation of a battery plant on such work, showed a net Watt-hour efficiency of 84 per cent.

On complete charge and discharge cycles, it is decidedly less, 87 per cent. with the ordinary stationary types of batteries being about as high as can be obtained, while under practical operating conditions it is less than this, running from 70 per cent. to 80 per cent. according to the class of work the battery is called on to do. In spite of this fairly low efficiency the use of such a "peak" battery may result in a very considerable saving. Most especially is this true when the source of supply is a water-power of limited capacity, and, as already pointed out, as an emergency it is invaluable.

**Journal I. E. E.*, Vol. XXX, p. 1070. See also Hopkinson, *London Electrician*, Vol. XLVIII, p. 211.

The capacity of a storage battery is given in ampere hours, and varies with the rate of discharge. Taking the capacity as 100 per cent. at the 8-hour rate, the capacities at the 5-, 3- and 1-hour rates are $87\frac{1}{2}$ per cent., 75 per cent. and 50 per cent., respectively. The capacity of a storage battery is arbitrary to a certain extent; that is, a battery could be discharged for a longer time than would correspond to these figures. If, however, the discharge is continued beyond these values, the voltage drops too rapidly for good efficiency. It should be noticed that by saying the capacity at the 1-hour rate is 50 per cent. of that at the 8-hour rate, we do not imply that twice as many ampere hours must be put in as are taken out, for this is not the case. The ampere-hour efficiency of storage batteries is very good, being 95 per cent. to 98 per cent.

To take care of the fluctuations on a power or sub-station, there are several ways of operating storage batteries. Necessarily, the voltage of a battery rises on charge and falls on discharge. If the generators have a falling characteristic, that is, the voltage drops with increasing load, and the maximum permissible amount of this drop is considerable, say 5 per cent. to 10 per cent., then a battery may be simply "floated" across the bus-bars, and will charge when the external load is light and discharge when it is heavy. The extent of the load equalization under these circumstances will depend on the sharpness of decrease in voltage, and the duration and magnitude of the fluctuations with reference to the size of the battery. Roughly, it may be stated that with a 5 per cent. to 7 per cent. variation of voltage above and below the normal and with current variations equal to the 1-hour rating of the battery, lasting for several seconds, the generator load variation will be constant to within 5 per cent. It is possible to adjust the combination of battery and generators for different load factors in either of two ways: first by cutting in or out a certain number of cells or by raising or lowering the average voltage of the station.

In many instances, however, it is essential that the voltage be maintained fairly uniform. Under these circumstances,

in order to have the battery charge and discharge, the difference in voltage between the battery and the system must be made up automatically in some way. It is usual to employ a differential booster for this purpose. A brief description of such boosters may not be out of place. There are two booster systems which have come into general use in America, both of which are usually motor-driven.

In the one form the booster generator field consists of a shunt winding, to which is opposed a series winding, a portion of this latter carrying the generator load, while through the remainder is passed the external load. The shunt winding is so determined that with no external load the voltage of the booster generator will be equal to the maximum difference of voltage between the battery and generators. The series winding is so determined that with both generator and external load equal to the average, the resultant field and consequently the booster voltage is zero. One of the objections to this arrangement is that the resultant field is small in comparison with either component, and in consequence there is a serious amount of energy dissipated in the field magnets. The field energy has practically the same value independent of the battery load, so that the amount of this loss is of considerable magnitude. The self-induction of these abnormally heavy windings is very great and the pole legs of the field magnets necessarily long to accommodate them; these two facts condition a relatively slow response of the booster to variations of the load.

In the second form, the booster-field regulation is obtained through the use of a small auxiliary generator, whose field carries the generator load. This machine is so determined that with the generator load at its normal value the voltage is equal to that of the system. The booster-field circuit includes the armature of this auxiliary machine and is connected across the generator bus-bars. The result is that, with the average current in the auxiliary machine field, the voltage impressed on the booster field, and consequently the booster voltage, is zero. If the generator load increases by a small amount, the voltage of the auxiliary machine increases by a corresponding amount, and there is

a resultant voltage impressed on the booster field, thus causing the booster to assist the battery to discharge. This machine may be so calculated that the generator load may be kept constant to within any predetermined limit. It has the advantage that there is no energy in the booster field when it is not required, and also that the regulation is dependent on the load which is to be regulated.

The length of the booster field magnetic circuit is normal, and the field windings are composed of a relatively small number of turns (for a booster on railway work usually wound for 50 volts maximum); as a result, the response of the booster is almost instantaneous.

The determination of the size of a battery installation will depend on two elements: the maximum discharge rate which it is required to deliver, and the required storage capacity. When a battery is simply to act as a load equalizer, independently of its storage capacity pure and simple, then it is obvious that the battery should be chosen on the score of cost as small as is consistent with efficiency and life. For this purpose that type of battery which is calculated to withstand a maximum discharge rate with the least amount of deterioration and least drop in voltage should be chosen. These properties attach to plates having a great surface exposed to the electrolyte in the cells.

The combination of equalization of both instantaneous fluctuations and peaks of the average load is especially useful with water powers of limited capacity, as it is possible then to obtain the maximum output capacity of the plant. Another very prominent advantage, especially in operating on comparatively low heads, is that the difficulties of governing are largely obviated. This is of extreme importance in alternating current installations.

An example of such an installation, at Easton, Pa., may be quoted. The power plant consists of two 2-phase alternators, driven by water-wheels, located in a station about 1½ miles distant from the main power-house. In this latter are steam-driven auxiliaries. A mixed railway and light service is furnished. Before the installation of this battery an 800-horse-power steam unit was in constant use to rein-

force two A. C. motor generator sets, driven from the water-power, in order to care for the instantaneous peaks of the railway load. Since the installation of the battery, the water-power carries both the railway and lighting load. During the day the battery equalizes the railway load, receiving also a slight net charge; when the lighting load comes on, the battery furnishes a net discharge to cover the difference between the water-power capacity and the total load on the plant. From 12 to 4 A.M., when the load is extremely light, the battery is re-charged. They are able then to carry their load under normal conditions without the use of steam, excepting for certain auxiliary service, and are able to shut down an 800-horse-power unit, and in addition to this advantage, by the removal of the railway load fluctuations, their lighting service is extremely satisfactory.

The preceding has reference to installations in central or sub-stations. Under certain conditions, it is advantageous to instali batteries at points distant from generating stations. Such installations are of two types—"floating," or fed from a boosted feeder, and are termed line batteries. In electric railway work such batteries would be located at some distance from the generating station to maintain the line voltage.

In the case of a battery at the end of a boosted feeder, it is usual to transmit the average current, allowing the battery to absorb or give up the difference between the instantaneous and average currents. Such an installation may have a very fair efficiency, and will show a decided advantage over a high-tension transmission and sub-station scheme if the frequency of the car service does not justify the first cost and attendance required by the latter. The instances where these conditions hold are extremely numerous in interurban work. In many cases, however, a battery simply placed across the line will serve every purpose of the above, and will show several advantages over it.

It is obvious that the voltage at different points could be maintained by copper, but the amount of copper would often be excessive. It is of great importance to maintain the voltage on the line at as high a value as is possible, for

several reasons. It is the charactertistic of series motors, such as are used in railway work, to take a definite current on definite grades outside of periods of acceleration and independent of the speed of a car. The speed will vary very approximately as the applied voltage; it is obvious, then, that to maintain a given schedule less cars will be required with high than with low voltage. Again, with cars on a grade or accelerating, the periods of taking excessive currents are of shorter duration with the higher voltage. The heating of the motors will depend largely on the time that these heavy currents are demanded, and as a result the motors will deteriorate and burn out very rapidly if the line voltage is too low. This item of motor repairs is a very serious one in electric railway operation. Again, the loss in transmission with low voltage is excessive. Taking into account the schedule speed and the transmission losses, the energy consumption will be approximately inversely as the squares of the applied voltages.

If the amount of copper is sufficient to furnish the average demands of the cars with a relatively small drop, when the cars are accelerating or mounting grades distant from the power-house, especially when the service is supplied by only a few cars, the drop becomes excessive, and is felt all over the line. If a battery be installed at a point about three-fourths of the distance from the power-house (which point would be modified somewhat by the location of grades), whose voltage is equal to the voltage which would exist at this point if all the cars were taking the average current, then it would charge on light loads and discharge when the load becomes heavy. This results in a very considerable equalization of load on the power-house and in the maintenance of the voltage at the battery location at approximately a constant value, varying only 5 per cent. to 7 per cent. above and below the average. The battery will then neither experience a net charge nor discharge. Such batteries have been installed by putting in the number of cells corresponding to the average voltage before the erection of the battery. It is easily seen that the two values, voltage at this point with the cars taking the average current, and

the average voltage, may be quite different, as the battery will modify the latter quite considerably.

An objection sometimes brought against such an installation is that it has no flexibility. It is, of course, absolutely determined by the feeder scheme and the service on the line. If the latter is increased, the battery will experience a net discharge. But this may be taken care of as follows: A certain number of cells may be cut out of service, corresponding to the increased drop; or if the schedule varies with the time of day, the battery may be installed so that it receives a net charge during the lighter service and furnishes a net discharge when the greater number of cars are run, or the voltage of the power-house may be correspondingly varied. Sometimes the conditions would be met by a combination of these methods.

A small installation, at Berlin, N. H., will illustrate what may be accomplished in this way. The road runs from Gorham to Berlin Mills, and is approximately 8½ miles long. The power-house is ·75 miles distant from the Gorham end of the line; from Gorham to Berlin there are numerous 3 to 5 per cent. grades, with one short, heavy grade of about 12 per cent. near Berlin; toward Berlin Mills there are several 8 per cent. grades. The track is 60-pound rail; bonding in poor condition. The line consists of one No. 00 trolley, with a 400,000 C. M. feeder to within 1 mile of the end; from Gorham to the power-house there is a 400,000 C. M. copper return. A battery was installed in the carbarn 6·5 miles distant from Gorham, consisting of 230 cells, having a capacity of 280 amperes for 1 hour. Ordinarily two 16-ton cars are operated under 40-minute headway. If extra cars are run for a short time, no change is made in the battery. If, however, it is desired to operate a 20-minute schedule over 8 or 9 hours, thirty of these cells are cut out and the battery furnishes a net discharge of about 40 amperes. Before the battery was installed, it was impossible to operate more than the two regular cars. They are now able to operate four cars for 8 to 10 hours, and at times six cars are run.

What promises to be an exceedingly useful application

of floating batteries on interurban roads operating substations at not too infrequent intervals is the installation of batteries in such sub-stations ordinarily to accomplish load equalization; in case of a breakdown of the sub-station of short duration, the battery would be placed directly across the line and allowed to discharge. If the breakdown is of long duration, a certain number of cells could be cut out and the battery "floated" between the two stations on either side to maintain the line voltage indefinitely at a value sufficient for continuous operation.

CHEMICAL ANALYSIS OF ROCKS.

A bulletin (No. 228) entitled "Analysis of Rocks from the Laboratory of the United States Geological Survey, 1880 to 1903," has been prepared under the direction of Mr. F. W. Clarke, the Survey's chief chemist, and is now ready for gratuitous distribution. During the four years that have elapsed since the last edition (Bulletin No. 168) was printed, over 1,000 analyses have been made, of which nearly 300 are included in this bulletin. In this edition the names are given which the rocks would bear in the classification proposed in 1903 by Messrs. Cross, Iddings, Pirsson and Washington in Professional Paper No. 14.

Over 5,300 analyses have been made in the chemical laboratory at Washington. These represent analyses of rocks, minerals, ores, waters, sediments, coals, metals and so on through all the range of substances with which geology has to do. A fair amount of research work has also been done upon mineralogical and analytical problems.

On account of the activity of the petrographers, the dominant feature of the laboratory work has been the analysis of rocks. These have been studied in great numbers and in the most thorough way. The results have appeared in widely scattered publications—in official reports, monographs, bulletins and American and foreign journals. The object of the present bulletin is to collect this valuable material, together with such bibliographic and petrographic data as seem necessary to identify the specimens and to facilitate chemical discussion.

Mr. Clarke has also given in this bulletin a new computation of the average composition of rocks, which agrees closely with his former estimates, but is founded upon more extensive data.

THE SIMPLON TUNNEL.

The Simplon Tunnel, when completed, says *Engineering Record*, will have a length of about 12·3 miles, and the heading from the Swiss side has been advanced 5 miles. In order to secure an adequate supply of air to the men working at the face, two parallel tunnels about 50 feet apart had to be

driven, the ultimate intention being to have one for the "up" and the other for the "down" traffic, but for the present, one bore will easily carry it, so that only one (No. 1) tunnel is now being completed. These two parallel tunnels are connected by cross-passages every 200 meters, though, as the heading advances, only the nearest cross-cut to the face is kept open. In No. 2 tunnel, that is, the tunnel not at present being completed, all the water pressure and air pipes are situated; it also carries the water flowing from the face of both tunnels. In advancing the heading, No. 1 tunnel is kept ahead of No. 2, so there is always a dead end beyond the nearest cross-cut to be ventilated. This ventilation is secured by laying a 14-inch pipe from the cross-cut air-current to the face, and using a high-pressure water injector, directed into the ventilation pipe, to force or induce air right into the face. The tunnel headings have an area of about 8 square meters, that is, about 7·5 x 10·5 feet, and at the time of my visit the rock through which they were advancing was *antigoro* gneiss. This rock, though very hard in places, is much split up and breaks easily; so much so, that in the face ten holes suffice for a round. A two-hole cut is sufficient, and the remaining holes are arranged symmetrically around the cut holes. Each hole is charged with 2 kilogrammes, or 4·48 pounds, of blasting gelatine, which is practically the same in composition as the explosives in use on the Rand. The actual work of drilling is performed by a set of three Brandt hydraulic drills, mounted on a horizontal hydraulic rack bar 12 inches in diameter, which is carried at the end of a pivoted lever, mounted on a four-wheeled lorry. By this arrangement the complete fixing, drills and rack bar can be run into position, the rack bar set at any convenient height across the tunnel and parallel to the face, and the latter firmly fixed in place, after attaching the valve of the rack bar to the pressure pipe and placing wood blocks at each end of the bar, by simply opening a valve.

ABSORPTION OF RADIUM EMANATIONS BY WATER AND PETROLEUM.

In a paper published in No. 8 of the *Physikalische Zeitschrift* (April 15, 1904), Prof. F. Himstedt arrives at the conclusion that radio-active bodies giving off a gaseous emanation are widely diffused throughout the earth. These emanations are absorbed by water or by petroleum; and after having been conveyed along with the latter to the surface of the earth, will diffuse into the air. Because of the many analogies noted between these emanations and radium emanations, the author thinks it possible that both are identical. In this case the ores of uranium from which radium emanations are derived would either be widely diffused, or else there would be some further matters possessing, though to a lesser degree, the property of giving off emanations. Considering that the absorption coefficient of water as well as of petroleum with respect to this emanation is found to decrease for increasing temperatures, while hot fountains on the other hand show an especially high activity, the hypothesis is suggested that the amount of radio-active material is increasing for augmenting depths, and, according to Curie's observation as to the continual heat evolution from radium, the radio-active components of the earth should possibly have to be allowed for in accounting for the temperature of the earth.

Ferrell's Apparatus and Process for Fireproofing Wood.

[*Being the Report of the Committee on Science and the Arts on the invention of Joseph L. Ferrell.*

Sub-Committee: Samuel P. Sadtler, Chairman; William McDevitt, Richard L. Humphrey, A. Raymond Raff.]

[No. 2261.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the process of fireproofing wood, devised by Joseph L. Ferrell, of Philadelphia, reports as follows:

The limited time which the members of your committee could devote to this work prevented them from making as exhaustive an investigation as they desired. They have, however, considered those features which they deemed most essential.

The term "fireproof wood" is misleading and a misnomer. No process thus far known can render wood "fireproof;" the best that is attainable is to so treat wood as to make it "fire-deterrent" or "fire-resistant." There is nothing new or original in this fact. The British patent records on the subject date from 1625; the United States patent records from 1790, while the Greeks and the Romans considerably antedate these in the use of alum as a fireproofing medium. Since then many substances have been proposed and employed to render wood "fire-resistant,"—among which may be mentioned silicate of soda, tungstate of soda, alum in various forms, sulphate of ammonia, borax and salt.

None of these, however, fills the requirements of an ideal fireproofing substance, which may be summarized as follows:

(1) To render wood "fire-resistant" in the highest degree.

(2) To have no deleterious effect on the wood, but, on the contrary, serve as a preservative.

(3) To have no injurious effect on the strength of the wood.

(4) To have no hydroscopic qualities.

(5) To produce no efflorescence.

(6) To preserve the natural color of the wood.

(7) To have no injurious effect on varnish or paint applied to its surface.

(8) To be non-volatile under the action of heat.

(9) To exert no corrosive or rusting action on metallic substances.

Having obtained such a substance it is necessary to devise some means by which it can be successfully applied.

In the investigation of the Ferrell process, the committee for convenience has considered (1) the mechanical features; (2) the chemicals employed, and (3) efficiency of the process.

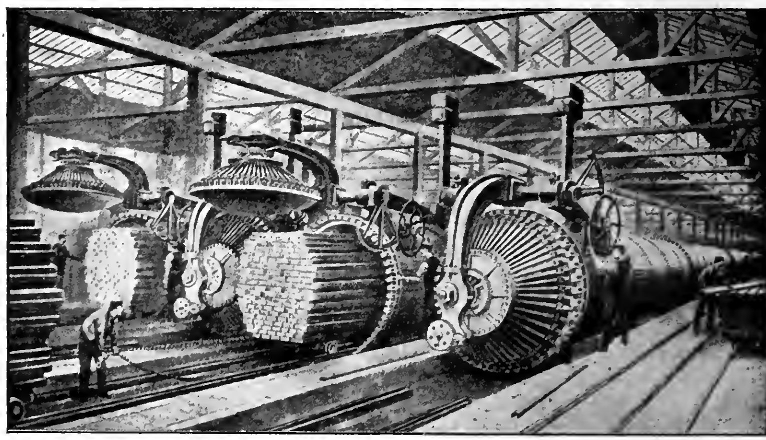

FIG. 1.—Old type of cylinder with external end-gate.

These inventions are the subject of U. S. letters-patent 620,114, February 28, 1899; and 695,678, March 11, 1903, granted to Joseph L. Ferrell, of Philadelphia.

Prior to Mr. Ferrell's inventions the apparatus in general use, and that still used, consists of a large cylinder closed at one end and provided with a movable hinged head at the other, fastened by means of a radial multi-locking system of bolts. This is a bad feature, since it prevents the attainment of high pressures which are desirable for the thorough impregnation of the wood. The cylinders required for practical work are generally so large that it is impossible to

maintain a pressure above 150 pounds. It requires much longer even to partially saturate the wood with such a pressure. (*Fig. 1.*)

In the Ferrell apparatus this objection is admirably avoided by means of an internally-seated gate or valve operated hydraulically. With this apparatus pressures from 400 to 1,500 pounds can be obtained. (*Fig. 2.*)

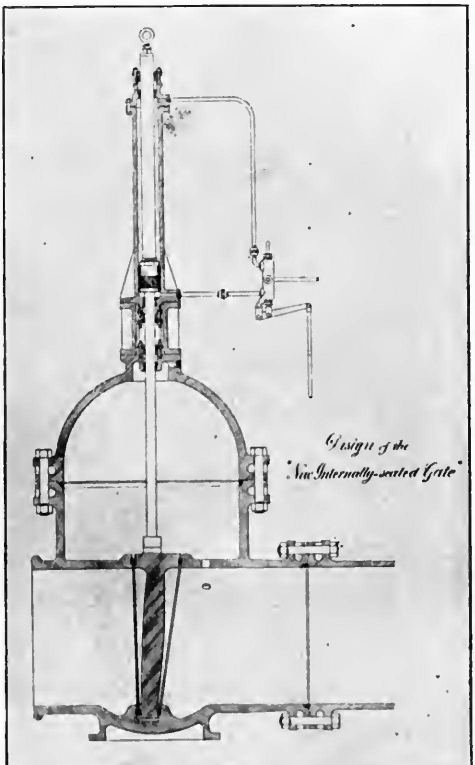

FIG. 2.—Section of internal end-gate.

Again, these cylinders are filled by high-pressure pumps, the shock from which tends to bruise and tear the wood fiber, particularly at the higher pressures. Mr. Ferrell has devised an accumulator which not only maintains a uniform pressure, but serves as a cushion for the pumps. It also serves as an indicator for determining the saturation point;

the pumps cease to act and the pressure is maintained nearly constantly when the wood is thoroughly impregnated. (*Fig. 3.*)

In most processes the treatment consists in depriving the wood of its sap, by first softening with steam, then extracting by drying in a vacuum. This often destroys the wood fiber and usually so reduces its strength that the United States Government, in its specifications for fireproof wood, provides that this loss of strength shall not exceed 30 per cent.

In Ferrell's process no preliminary treatment is required,

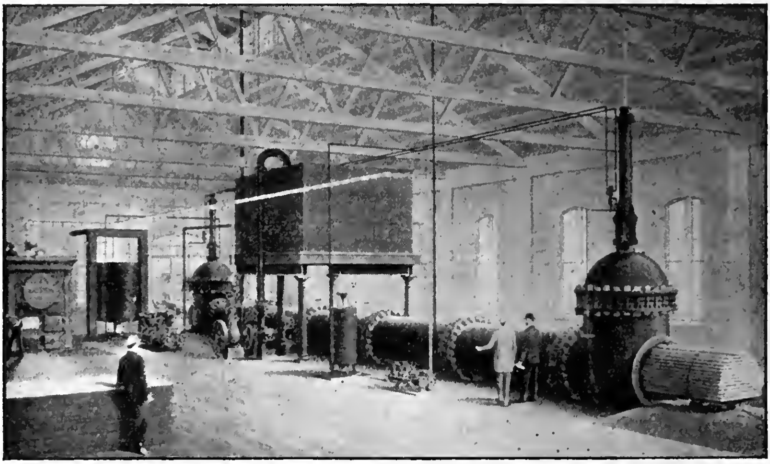

FIG. 3.—Cylinder used in Ferrell's process, showing internally seated end-gate.

the wood is placed in the cylinder at once, saturated at a given pressure, then taken out and dried.

In order to determine whether the wood fiber was injured in the slightest degree by the high pressure of the Ferrell process, the committee had prepared a series of large and small test specimens made from representative hard and soft woods for compression and transverse tests and for the determination of the percentage of saturation and the brittlizing effect of the process.

The compression specimens were 4 and 8 inches long, with a section of 1 x 2 inches and 4 x 4 inches respectively,

while the transverse specimens were 36 x 18 inches long and had a section of 4 x 4 inches and 1 x 2 inches respectively. Six specimens of each variety of wood were prepared for each test, one-half of which were treated by the Ferrell process. Mr. Ferrell prepared a similar set, making a total of over 480 specimens.

The tests are not quite finished, but the results will be presented in a final report.

The results of the tests thus far obtained seem to indicate that it is possible to secure a saturation ranging from 25 to 100 per cent. without apparent detriment to the physical qualities of the wood. Soft woods appear to be more readily saturated than hard or resinous woods.

Several visits were made to Mr. Ferrell's experimental plant, and his apparatus was thoroughly examined, as a result of which the committee feels that the inventor has devised and perfected an apparatus that fulfills all the requirements admirably, and that by means of this apparatus it is possible to saturate wood (without injury to its structure) far more quickly and thoroughly than by any other existing machine. That the saturating solution penetrates the very heart of the wood, following the medullary rays from end to end, is another important feature of the Ferrell process.

In his treatment of the chemical phase of the process Mr. Ferrell has been equally successful in the use of sulphate of aluminum. As far as we have been able to determine, this salt possesses most of the desirable qualities of the ideal substance, and we find that wood properly impregnated with it will resist the point of a Bunsen burner for over eighteen hours, a very much longer time than wood treated by other processes.

Under such temperatures the salt is decomposed, leaving an infusible, non-conducting residue to cover and protect the fiber of the wood, in which condition it will not of itself support combustion.

Most of the other salts employed are decomposed and volatilized by such heat—the evolution of a gas or vapor retarding the action of the flame for only a short time.

Sulphate of aluminum preserves the wood, does not promote the growth of fungi, is not hydroscopic, does not produce efflorescence, and does not corrode or rust metallic substances. It has one bad feature, which Mr. Ferrell claims, and appears, to have successfully corrected. The commercial sulphate of aluminum used in the process contains free sulphuric acid, which acts on the iron of the cylinder in conjunction with the tannic acid in the wood, and forms tannite of iron, which blackens the wood. Mr. Ferrell corrects this by neutralizing the acidity with magnesium or ammonium carbonate.

Paint or varnish applied to treated wood remains unaffected for a long period of time.

The committee has also observed a large number of flame tests made (using Bunsen burners) on samples of treated wood of various kinds, and has found that the wood treated by the Ferrell process resists this flame action much longer than wood treated by any other process.

Mr. Ferrell has admirably and greatly perfected the chemical and mechanical features of the art of rendering wood "fire-resistant," and has made it commercially far more available.

In consideration of the fact, therefore, that he has performed a signal and most notable service in his perfection of the process and apparatus for rendering wood "fire-resistant," he is entitled for his investigations to the award of the Elliott Cresson Medal.

Adopted at the stated meeting of the Committee on Science and the Arts, June 10, 1903.

Attest: WM. H. WAHL,
Secretary.

WAGON WITH TWO FIFTH-WHEELS.

A wagon gearing with two fifth-wheels is the invention of Theodore Sandstrom, of Connorsville, Ind., the object being to permit very short turns of the vehicle, and to prevent it from being overturned in case of a runaway or accident. One of these is in the usual place on the front axle, and the other is on the rear axle with a cog connection, so that when the front wheels are turned, the rear ones will be inclined in the opposite direction.—*Scientific American.*

The "Kodak" Developing Machine.

[*Being the Report of the Committee on Science and the Arts, on the invention of Arthur W. McCurdy, of Toronto, Canada.*
Sub-Committee: Lucien Picolet, Chairman; Wm. O. Griggs, J. W. Redpath, Samuel Sartain, Urbane C. Wanner.]

[No. 2266.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the invention of Arthur W. McCurdy, of Toronto, Canada, reports as follows:

The awkward tendency of photographic roll-films to curl up in the process of development, the consequent handling required and undue exposure to the dark-room light, have led the manufacturers of this product, the Eastman Kodak Company, of Rochester, N. Y., to place on the market a device with which development can be carried on without the aid of a dark-room and without any handling of the film whatever until it is developed and fixed.

The apparatus is adapted to treat what is known as "daylight film," that is, film covered in the back, its full length, with a strip of black paper before reeling to enable it to be inverted in the camera and removed from it in daylight without injury.

The most obvious method of reducing the amount of handling required to develop each separate picture is to develop the entire film at one operation—a practice of no very recent date among professional operators. A simple apparatus for doing this would consist of a cylindrical roller placed at the bottom of the developer recipient under which the film, face outward, could be drawn back and forth. Enlarge the roller until its circumference is equal in length to the film to be developed, provide means for attaching it thereto, at the same time keeping it tightly drawn against the surface, add a crank for rotating the cylinder and a light-tight cover, and we have the kodak developing machine in its most elementary form.

A cylinder large enough to hold a film of the usual length would be inconveniently large, and in the perfected machines

it is replaced by a flexible strip of celluloid somewhat larger than the film with a strip of corrugated rubber along the full length of each edge. When this is rolled up it forms a spiral with a space between the adjacent coils equal to the thickness of the rubber edging. If the film is rolled along with it, face outward, it occupies the same relative position with respect to the spiral surface as it did in the previous case with respect to the cylinder. This may be mounted on a mandrel and submerged in the developer which finds its way through the corrugated edging between the convolutions of the spiral to the film surface. The complete apparatus is shown in *Fig. 1*, and is manufactured under letters-patent No. 647900, granted to Arthur W. McCurdy, April 17, 1900.

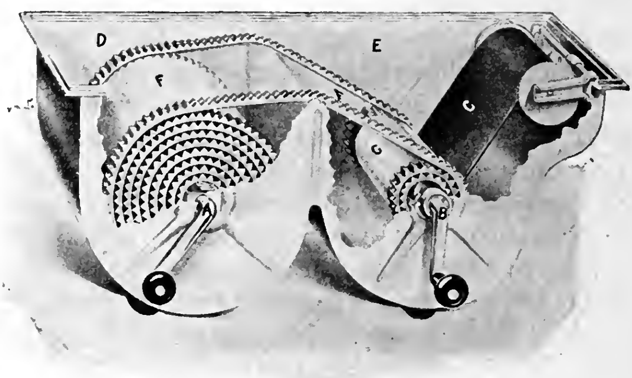

FIG. 1.—Kodak developing machine.

It consists of an oblong metallic, fluid-tight box, divided into two compartments, *D* and *E*, through which pass mandrels *A* and *B*. Compartment *D* merely carries the celluloid strip or "apron" before use, which is transferred to compartment *E* along with the film during operation. A clamp *H* is provided to carry the film spool *K*.

Placing the spool in the holder *H*, a short length of the paper backing *C* is threaded to the spindle *B*, to which is also attached the end of the apron *F*. Enough developer is poured into *E* to half fill it. The box is then covered and the apron *F* and paper strip *C* carrying the film are completely wound upon *B*. With standard developer and at the

usual temperature of living-rooms these are kept in rotation for about five minutes, when development is complete. The developer is then poured off and without any rinsing the fixing bath is introduced and the rotation is continued until the fixing is complete.

Close contact between *C* and *A* is secured by frictional resistance applied to the spool *K* as *C* unwinds. No provision is made for holding the loose end of *C* in contact with the apron *G*, dependence being placed on the adhesive properties of the wet paper, which, being considerably larger than the film, preserves the tension on that part of the paper carrying the film in much the same manner as a comparatively slight tension on the "slack side" of a belt running over a pulley with a large arc of contact will produce a much greater tension on the tight side.

It may be questioned whether treating exposures made under widely varying conditions in the same developer for the same time would not result in many failures. The manufacturers claim that by using the developer they recommend, pyrogallic acid, great latitude in exposure is allowable.

Three six-exposure films, exposed by the Kodak *C*, were developed according to their printed directions. The subjects are outdoor views taken, probably, under one condition of lighting. The excellence of the resulting negatives, submitted herewith, demonstrates without doubt the capabilities of the device for normal exposure.

To further test the machine with varying exposures, three indoor exposures of the same subject were made of five, ten and twenty seconds on a film containing "snapshot" outdoor exposures. The results were perfectly satisfactory and leave little doubt that great latitude in exposure is allowable.

For the excellent performance and certainty of action of the machine and the ingenuity shown in devising the simple and efficient means leading thereto, the Institute recommends the award of the John Scott Premium and Medal to the inventor, Arthur J. McCurdy.

Adopted at the stated meeting of the Committee on Science and the Arts, March 4, 1903.

Attest: WM. H. WAHL, *Secretary.*

Sprague's Multiple-Unit System of Electric Traction.

[*Being the Report of the Committee on Science and the Arts on the inventions of Frank J. Sprague.*
Sub-Committee: W. C. L. Eglin, Chairman; Arthur Falkenau, D. A. Partridge, Clayton W. Pike.]

[No. 2250.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the "Multiple-Unit System of Electric Traction," invented by Frank J. Sprague, of New York, reports as follows:

The object of this invention is to permit railroad managers to operate trains made up of any number of units with equal facility, and to enable the train to be rapidly accelerated and maintain the maximum tractive effort on the wheels. This is accomplished by making each unit a motor car and attaching a controlling cable to all controllers, so as to enable the various units to be combined in a train, and operated by a single controller at each end of the train.

The system of control is covered by United States patents:

660065—October 16, 1900.
660066—October 16, 1900.
696880—April 1, 1902.

A brief description of the Sprague system is as follows:

In the hood of each car is a controller for the motors enclosed behind a trap-door which can be lowered for ready inspection. The controller is of the multiple-series type, is driven by a small pilot motor, and provision is made for at will or automatically producing a step by step, or interrupted, or periodic forward movement of the controller, and a continuous or interrupted return movement of it to the off-position through various automatics connected with the pilot motor and the initial control circuits.

In addition to the current-varying controller, there is a main reverser, likewise operated by the same agencies as

the pilot motor, for determining the direction of the current delivered to the motors, and for instantly opening the circuit of the motors in case of emergency.

Inside of each cap is a small master controller or operator's switch mounted on a standard, and fastened to the wood-work of the cab. Through this master controller the pilot apparatus of the current-varying controller and reversers are governed. It is provided with a movable handle, operating a spring-retracted spindle, which, through various degrees of movement, makes contact with the reverser circuit and with three determinate positions, coast, series and multiple. Momentary contacts on these various points give a desired intermediate position of the main controller, which has a stepped movement. In order to maintain the controller at any point, or to keep the governing circuits or train lines energized, the handle of the master controller must be held in position. If the handle is released, whether from accident or design, the spindle instantly returns to coast position, and the controller automatically returns to the off position and cuts off the current, or, if the master controller is allowed to go to the center position, the reverser is instantly opened, and the controller then comes to open circuit also automatically.

The arrangements of circuits is such that by the use of a relay and throttle and the proper interconnection between the controlling circuits the operator is at liberty to do about as he pleases with the master controller, and can rely upon the main controller operating satisfactorily.

For example: He can go to the series or to the multiple position, or, from the last, reverse movement instantly, and the controller instead of responding instantly operates progressively, the pilot being limited in its movements by increment of the main current to or above any definite amount.

The throttle is set just short of the skidding point of the wheels on a normal track, allowing 15 per cent. adhesion, and absolutely limits the current input to that which is required by the determined rate of acceleration. Any rate less than this can also be effected by proper handling of the

motor controller, so that any movements, no matter how refined, are perfectly possible.

This throttle is in the circuit of one motor only, so that it is equally effective, whether in the series or multiple position.

Although there is a master controller on each platform, their construction is such that interference with them is difficult, and has never been known to occur. Of course, they could be made removable.

So far the system described is that of a secondary electric control of a single controller, but by paralleling the relay and other circuits it is evident that the two or more equipments on a single car can be operated, and also that if these equipments are on different cars they can likewise be operated provided means exist for properly connecting the prime controlling circuits, and insuring practical synchronism of the different controls and equal work on the different motors. Where the equipments, however, are on different cars, it then becomes necessary to have a "train line" and couplers, so that a governing circuit, which can be energized at various points, is made up of a train line individual to each car and couplers of some kind between them.

When trains are made up, the train lines are connected by a reversible jumper having corresponding wires, and the system is so disposed and connected that, no matter from which corner the connections are made, or how the cars are reversed or altered in sequence, the circuits are automatically established, so that like track movement is always assured, with like hand movement of the master controllers.

The section of train line in each car is not a part of the normal controlling circuit individual to the control equipment, but is connected with it with switches, which enables a severance of the two systems; that is, the local car system and the train line, so that, no matter how trains may be made up, it is always possible to disconnect the controlling mechanism of any train for any purpose whatever.

The practical result of the system is that every aggregation of cars, whether one or more, has identically the same characteristics in the matter of load, capacity, motor, equip-

ment, rate of acceleration, etc., as are possible with a single car, and every combination is made without the slightest thought being given to pairing of electrical circuits.

Each car is equipped with an automatic air brake system, supplied by Christensen air compressors, with a reserve tank and an equalizing pipe running from car to car, the compressors being started and stopped automatically through an air-governed switch by fall and rise of air pressure.

On each platform, alongside of the master controller, is a small engineer's valve, so that from any selected cab the air-brakes can be operated with equal facility.

A balance wire runs throughout the train, and is included in the same coupling as connects up the electrical train line, so that when an air-governor on any car closes circuit, all compressors start and continue in operation until the last governor throws out. This is to effect equal work on the various compressors, and to maintain absolute certainty of air supply at all times.

If the train should part, three systems of automatics come into play. The reversers go to open circuits, the controllers to the off position, and the air-brakes also automatically operate.

If the main circuit fails, all reversers open instantly, and the controllers must come to the off position, which they will do automatically as soon as current is restored, before current can again be put in the main motors.

So, too, if there is an instant reversal of the master controller. The reversers first open circuit, the controller returns to the off or any determined position, then start again, and are instantly arrested on the first contact. Provision is made so that it is impossible to run backward at more than one-half speed from any platform when operating from that platform.

It would appear that there are two meritorious characteristics presented: First, the system or scheme of train operation by combining motor units, which, we believe, was first suggested by Mr. Sprague. Second, a method of successfully accomplishing this result.

The investigating committee has carefully examined the

various diagrams and printed matter presented, and find that all of the requirements have been carefully and ingeniously worked out. The committee also has communicated with some of the railroad companies using this system, and in their replies they have endorsed its practical success.

In view of the many obstacles which the inventor had to overcome, and because of the very important advance which his inventions have made in the operation of railroads by means of electricity, not only reducing the cost, but also facilitating the transportation of passengers, the award of the Elliott Cresson Medal is made to the inventor, Mr. Frank J. Sprague.

Adopted at the stated meeting of the Committee on Science and the Arts, April 1, 1903.

Attest: WM. H. WAHL,
Secretary.

Notes and Comments.

EXPERIMENTS ON THE RATIO OF GRATE SURFACE TO HEATING SURFACE OF STEAM BOILERS.

At the works of the Yarrow shipbuilding firm of London, interesting experiments have been carried out concerning the ratio of the grate area to the heating surface of boilers. This is an important consideration, as upon this proportion depends to a very appreciable extent the efficiency of the boiler, especially if it is of the water-tube type. For the purposes of these tests a water-tube boiler equal to 1,200 indicated horse-power was employed. This boiler had 1,008 tubes, each 1¾ inches outside diameter, with an average length of 6 feet 9¼ inches. The test was conducted with a boiler having 53 square feet of grate, and with 3,217 square feet of heating surface, giving a ratio of 1 to 60·7. In the second test the grate was reduced to 40 square feet, with a slight change in the heating surface, giving a ratio of 1 to 78·2. The results showed that there was a much higher evaporative efficiency with the smaller grate. Each pound of fuel consumed gave with the small grate 10·57 pounds of steam, while in the other case it only gave 9·96 pounds. But it was also decided that, irrespective of this, the same boiler should give an equal volume of steam, and thus the quantity of coal consumed per square foot of grate had to be increased. For instance, with the larger grate the rate was 29·7 pounds of fuel, and with a less area 39·31 pounds. To burn the greater quantity more draught was required, 0·75 inch as compared with 0·56 inch. These results are highly valuable, for the greater efficiency of the small grate would reduce the fuel consumption on a vessel to a very appreciable extent. The explanation of this greater efficiency is that the gases of the fuel

are consumed more quickly, and are not so likely to come into contact with the cold surfaces of the tubes in an unburnt state.—*Scientific American.*

PRODUCTION OF MICA IN 1902.

With the passing of the stove and the coming of the register and radiator, one of the chief uses of mica has declined. On the other hand, there is an increased demand for smaller pieces of mica that were formerly thrown on the scrap pile. The variations in use, production and importation of this familiar mineral are set forth in a report on the "Production of Mica in 1902," by Dr. Joseph A. Holmes, an extract from the annual volume of "Mineral Resources," published by the United States Geological Survey.

The total quantity of mica produced in the United States during the year 1902, as reported to the Survey, was as follows: Plate mica, 373,266 pounds, valued at $83,843; scrap mica, 1,028 short tons, valued at $13,081; and mica rough as mined, or unmanufactured, 372 short tons, valued at $21,925, making a total value of $118,849.

The increase in the production of plate mica during the last three years is due to the increasing quantity of small-sized mica disks and rectangular sheets that have been cut for electrical purposes. Some of the small, clear pieces obtained in cutting up the large sheets are now split very thin, re-arranged and cemented closely together, forming large sheets called micanite, which are then cut into the shapes and sizes desired. For some purposes these sheets of micanite answer as well as the natural sheets, and have the advantage of being much cheaper. In recent years, scrap mica has been manufactured into a covering for boiler tubes and steam-pipes, to take the place of the more expensive asbestos coverings. Waste mica not available for other purposes is used in the manufacture of wall-papers and lubricants. During 1902, there was, however, a large falling off in the production of scrap mica, which, in 1902, amounted to 1,150 short tons, valued at $14,606, as against 2,171 short tons, valued at $19,719 in 1901.

The tables, which show the great increase in the importation of mica during 1902, are significant. This increase, valued at $131,278, is larger than the total value of the product of mica in the United States during 1902. It illustrates the increasing demand for mica in this country, but also suggests the sad fact that mica can be mined in India and landed in this country at a lower price than it can be mined in some places in the United States. Canada is also a large contributor to our mica supply. It is unfortunate for the industry that many of our mines are owned by small producers who are entirely dependent upon one little mine. When the mica in this begins to give out, or is poor, they have no means to carry on much dead work, and have no other deposit to help fill out this deficiency.

Although mica is widely distributed in the United States, actual mining has been limited, during the last few years, to North Carolina, New Hampshire, South Dakota, New Mexico, Idaho, Virginia and Colorado. Some development work has also been carried on in California, Nevada, Maine, Alabama and Georgia. In several of these States good deposits of mica are known to exist that are not now available on account of their distance from railroads or other means of transportation.

BOUNDARIES OF THE UNITED STATES.

A publication that finds a logical place in the library of both the historian and the geographer is a bulletin (No. 226) entitled "Boundaries of the United States and of the Several States and Territories, with an Outline of the History of all Important Changes of Territory," which has just been published by the United States Geological Survey for gratuitous distribution. The author is Mr. Henry Gannett, who prepared this paper in its first form in 1885, when it was published as Bulletin No. 13. A second edition, much enlarged, constituted Bulletin No. 171, published in 1900. The present work is therefore a third edition, and is its own recommendation.

Besides giving the present boundaries of the country and of the several States and Territories, as defined by treaty, charter or statute, Mr. Gannett presents briefly the history of all important changes of territory and the laws appertaining to those changes. He shows how the boundaries of our country have been affected by the provisional treaty of the United States with Great Britain in 1782, by the treaty with Spain in 1798, by the definitive treaty with Great Britain in 1783, by the treaty of London in 1794, by the treaty of Ghent in 1814, by the treaty with Great Britain in 1842 and by the Webster-Ashburton treaty with Great Britain in 1846.

The additions of territory that have come to the United States and the consequent changes in boundary lines are described. They include the Louisiana purchase, the Florida purchase, the Texas accession, the Mexican cession, the Gadsden purchase, the Alaska purchase and the acquisition of the Hawaiian Islands, Porto Rico, Guam, the Philippine Islands and Tutuila.

An historical review is given of the changes that have occurred in the public domain. A detailed account is also presented of the way in which the present boundary lines of the various States and Territories have been developed. The bulletin, in short, contains in convenient form a great quantity of information that will be useful to the student, teacher, legislator and general reader.

BRONZE FOR HEAVY GUNS.

A pamphlet has been published by the Austrian War Ministry concerning the utilization of bronze instead of steel in the manufacture of heavy guns. Austria is now the only country which employs bronze as the material for its heavy cannon, and it is the intention of the government to retain it. This official pamphlet states that this bronze, forged according to a secret process, is equal to nickel steel. Moreover, the cost of the inner tube is three-fifths less than that of the steel tube. Another advantage is that an injured bronze gun can have a new jacket fitted to it, which is difficult with a steel one. Lieutenant Field-Marshal Uchatius, who in the seventies discovered a special process for forging bronze, also found that good homogeneous bronze could be hammered in a hot or cold state, and therefore can be improved in quality. Lieutenant Field-Marshal Frederick Thiele, the present director of the Vienna Arsenal, also obtained very favorable results in forging this metal, producing a kind of bronze not surpassed by the best cannon steel, through a combination of metals, careful alloying and judicious rolling.—*Engineering and Mining Journal.*

THE RUSTING OF IRON.

W. R. Dunstan publishes a summary of the present results of an unfinished inquiry into the reactions involved in the rusting of iron. While both liquid water and oxygen are necessary for the formation of rust, the presence of carbonic acid is not essential, although it may accelerate the action. The well-known effect of alkalies and alkaline salts in preventing oxidation of iron has been hitherto attributed to the withdrawal of the carbonic acid. It has been found, however, that the phenomenon is not due to this cause, but to the establishment of conditions in which the production of hydrogen peroxide is inhibited. When highly purified iron, containing mere traces of impurity, is left in contact with dry gases (oxygen, carbon dioxide, mixtures of oxygen and carbon dioxide), rusting does not take place. In the presence of the same gases and water vapor, no rusting occurs so long as a constant temperature (34° in the actual experiments) is maintained; but if the temperature is allowed to fluctuate, liquid water condenses on the surface of the iron and rust is produced. It is thus shown that pure iron is not oxidized in presence of gases and water vapor only, but that the presence of liquid water is necessary for rusting to take place. In another series of experiments pieces of iron were left in contact with water saturated with a particular gas and with an atmosphere of the same gas above the solution. When hydrogen, carbon dioxide or nitrogen which had been carefully freed from oxygen was employed, rusting did not occur, but if oxygen or a mixture of oxygen and carbon dioxide was used, oxidation took place. From these results, it is evident that for the formation of rust both oxygen and liquid water are required. In the experiments in which a mixture of oxygen and carbon dioxide was used, the results observed indicated that in this case a secondary action proceeds simultaneously.—*Proc. Chem. Soc.*

Book Notices.

Werkstatt-Betrieb und Organisation, mit besonderem Bezug auf Werkstatt Buchfuehrung, von Dr. phil. Robert Grimshaw. Hanover: Gebr. Jänecke, 1904. (Price, Rm. 20.)

This work, as explained by its title (Shop Management and Organization, with Special Reference to Shop Bookkeeping), gives all the details of shop management, book- and time-keeping in the most prominent American shops, illustrating several hundred forms, slips and cards used in shops and offices to accompany the raw material through all its stages in the different shops until it becomes a completed article ready for use or shipment.

It is fully explained how all this, arranged into a system, complete for each particular purpose, enables manufacturers to obtain their productions with the least expense in the shortest possible time, and with almost absolute security against failure, losses and mistakes, and that the introduction of such systems has enabled American manufacturers, in spite of greater cost of labor and material, to compete successfully with their European rivals, not only in supplying articles cheaper, but more perfect in every way. The introduction

of labor-saving machinery, of piece work and premiums, etc., is shown as forming part of these systems, and is ably treated in this work.

That it has been possible to obtain all this information for publication certainly speaks well for the public spirit of our manufacturers, and the author pertinently remarks that their liberality is in direct proportion to their enterprise, progress and reputation. H.

Ready Reference Tables. Volume I. Conversion factors of every unit or measure in use, including those of length, surface, volume, capacity, weight, weight and length, pressure, weight and volume, weight of water, energy, heat, power, force, inertia, moments, velocity, acceleration, angles, grades, time, electricity, magnetism, electro-chemistry, light, temperature, money, etc., etc., based on the accurate legal standard values of the United States. Conveniently arranged for engineers, physicists, students, merchants, etc. By Carl Hering, M.E., Past President American Institute of Electrical Engineers, etc. First edition. New York: John Wiley & Sons; London: Chapman & Hall. 1904. (12mo, pp. xviii + 196.)

The author in this volume substantially enlarged and elaborated an earlier publication relating to the same subject. He appears to have spared no trouble to make his conversion tables thoroughly reliable. He claims that his figures are not mere compilations from existing books on the subject, but that they have been specially re-calculated for this volume from legal fundamental values specially obtained, where such were obtainable, from the National Bureau of Standards, the Director of the Nautical Almanac, the United States Coast and Geodetic Survey, and, in other cases, from the recommendations of various International Congresses, National Societies and from the best authoritative sources elsewhere accessible.

With this assurance from an author of Mr. Hering's reputation, engineers and others will doubtless feel disposed to accept the results of his work with gratitude. The time- and labor-saving to the professional man, which this work represents, can only be properly appreciated by an inspection of its contents. W.

Éléments de Chimie Inorganique. Par Prof. Dr. W. Ostwald. Traduits de l'Allemand par L. Lazard. Première partie. Metalloides. (8vo de ix + 542 pp., avec 106 figures.) Paris: Gauthier-Villars. 1904. (Price, 15 francs.)

The present French translation of the first part of Ostwald's well-known work on inorganic chemistry has been edited and revised by the translator from the second edition of the German original. It embraces the consideration of the modern concepts of physical chemistry, of which Ostwald is one of the most eminent exponents, and the metalloids. W.

The Practical Photographer. Editors, Rev. F. C. Lambert, M.A., Thos. Harrison Cummings. Boston: Photo Era Publishing Company. Monthly. (Price, 25 cents per number.)

This new photographic periodical represents what may be termed a new departure in serial literature of its class, inasmuch as each number is devoted exclusively to the treatment of a single branch or feature of the art. Thus the first impression (April, 1904) is devoted to "Trimming, Framing and

Mounting;" the second to "Printing on Bromide and Gaslight Papers;" and the third to "Developing and Developers."

The publication is well printed and fully and attractively illustrated. The articles in each issue are from authors of repute.

The field of periodical photographic literature is already over-crowded; but the special and original features of this new candidate for admission to its ranks should command for it a favorable consideration. W.

Jahrbuch der Elektrochemie. Begründet und bis 1901 herausgegeben von Prof. Dr. W. Nernst und Prof. Dr. W. Borchers. Berichte über die Fortschritte des Jahres 1902. Unter Mitwirkung der Herrn Dr. P. Askenasy, Nürnberg, u. A., herausgegeben von Dr. Heinrich Denneel, ix Jahrgang. (8vo, pp. ix + 750.) Halle a. S. Verlag von Wilhelm Knapp. 1904. (Price, M. 24.)

No more convincing evidence of the tremendous strides that have been made within recent years in this branch of applied chemistry can be found than is afforded by an inspection of this imposing volume of 750 pages, in which is set forth with encyclopedic conciseness the noteworthy items of progress for the year 1902. The field appears to have been covered with the same thoroughness that has characterized the previous volumes of the series, and being the only authoritative year-book on the subject, it is simply an indispensable work of reference. W.

De l'Accapanement. La concentration industrielle en France. Par Francis Laur. Ancien deputé de la Siene et de la Loire. Lettre-preface de M. J. Méline, Senator des Vosges, etc. (Tome troisième Deuxième edition.) Société Anonyme des Publicators Scientifique et Industrielle. Paris, 1905.

This volume is devoted to the consideration of questions growing out of the adaptation of French manufacturers to the modern "trust" methods, which have wrought so radical a change in the methods of American manufacturers. W.

Les Applications des Aciers au Nickel avec un appendice sur la theorie des Acier au Nickel. Par Ch. Ed. Guillaume. Paris: Gauthier-Villars. 1904.

This volume gives in concise form the modern views, derived from experiment, of the various kinds of nickel steel and a consideration of the theory of the subject. W.

Committee on Science and the Arts.

(*Abstract of the proceedings of a special meeting, held Tuesday, June 21, 1904.*)

PROF. LEWIS M. HAUPT in the chair.

Present, 19 members.

The meeting proceeded to the consideration of reports, as follows:

(No. 2186.) *Tangential Water Wheel.* Wm. A. Doble, San Francisco, Cal. (A re-investigation.)

ABSTRACT: A report was made on this application at the committee's stated meeting held October 1, 1902, and a brief abstract thereof was pub-

lished in the JOURNAL of the following month (*vide*, Vol. CLIV, p. 397). This was made the subject of a protest from the Pelton Water Wheel Company, of the same place. A reconsideration of the report followed, and the whole subject was reviewed by the sub-committee. An amended report was presented, and after due consideration was adopted at the special meeting above named. Its conclusions are as follows: "Although the Institute recognizes, principally, the original work in the ellipsoid bucket (of the inventor), it also wishes to recognize the improvements in the nozzle, and therefore recommends the award of the John Scott Legacy Premium and Medal to Wm. A. Doble, of San Francisco, Cal., for his improvement in the form of buckets for tangential water wheels, and for his successful adaptation of engineering principles to nozzles for the design of a new form." (*Sub-Committee*, Arthur M. Greene, Jr., chairman, Edwd. T. Child, John E. Codman.)

(No. 2279.) *The Invention of the Electric "Buzz" Fan.* Dr. Schuyler S. Wheeler, Ampere, N. J.

ABSTRACT: Dr. Wheeler's claims that were investigated by the committee were to the effect that he had been the first to devise and perfect a practical and efficient fan motor substantially the same as that in use at the present time.

The sub-committee, after a personal investigation of the evidence submitted by Dr. Wheeler, and an extended examination of the available literature bearing on the subject, solicited and received from a number of experts, presumed to be familiar with the history of this branch of the electric art, an expression of their views as to the accuracy of Dr. Wheeler's claims, and the answers received were so uniformly favorable, in all cases where a positive expression of opinion was given, that the sub-committee felt justified in admitting the applicant's claims, that he was the first to devise an efficient apparatus for this purpose for use on commercial circuits.

The award of the John Scott Legacy Premium and Medal is accordingly made to Dr. S. S. Wheeler for his contribution to the practical development of the electric fan motor. (*Sub-Committee*, Francis Head, chairman, Richard Gilpin.)

(No. 2281.) *Reducing Attenuations in Long-Distance Telegraph and Telephone Lines.* M. I. Pupin, New York.

(Protested by Mr. C. J. Reed. Report referred back for consideration.)

(No. 2294.) *Coal-Loading and Screening Machine.* Henry Jerome Seitz, Philadelphia.

ABSTRACT: The machine is the subject of United States letters-patent No. 681,142, August 20, 1901, granted to H. J. Seitz, and has for its object the loading of coal from piles into wagons, and, incidentally, screening the material.

Without the aid of illustrations, a general idea only can be given of its construction and operation. It is mounted on wheels so that it may be advanced into the pile, or moved from one pile to another. The power is transmitted through chains from the steam engine to the rear wheels, either wheel being operated at will by means of clutches.

The same engine drives the elevator and scraping conveyor. The latter is hinged on the front of the frame, and so arranged that its outer end may be

moved in a vertical plane to conform to the pile of coal. The purpose of the scraping conveyor is to supply coal to the elevator. The coal is discharged into chutes, and is screened during its passage to the wagons. If desired, two wagons may be loaded at the same time.

The machine examined by the committee loaded about one ton per minute and appeared to be an efficient machine. Six (6) men were formerly employed for this purpose, while, with the machine, but two (2) were needed.

The report concludes that while the machine does not embody much that is original, it is nevertheless an efficient combination of parts. A Certificate of Merit is awarded to applicant. (*Sub-Committee*, Chas. Day, chairman; Thos. P. Conard, Kern Dodge.)

(No. 2307.) *Automatic Electric Semaphore Signal.* J. William Lattig, Wyncote, Pa.

ABSTRACT: This invention is the subject of the following letters-patent of the United States granted to applicant, viz., Nos. 496,786–7, May 2, 1893, and 499,125–6, June 6, 1893.

After reference to some correspondence with manufacturers on the subject of prior inventions in this field, to wit, Automatic Electric Disc Signals, Automatic Semaphore Signals operated by means of compressed air electrically controlled, and Electric Semaphore Signals for use in interlocking plants, the report continues:

"What Mr. Lattig actually did was to design a train gearing that, by taking eight or ten seconds, would enable him to work a semaphore by means of an electric motor energized by from ten to twenty cells of potash battery. Mr. Lattig took an electric motor actuated semaphore signal and an electric control and operation—both already old in the art—and combined them.

". . . A few of the Lattig signals have been used on the Lehigh Valley Railroad for a number of years, and the signal itself forms the basis of a number of improved signals now coming into more general use."

The report finds that the applicant was the first to devise a practical automatic electrical semaphore signal, which, though embodying essential features of prior patents (Farrar, Ramsay and Weir), constituted, nevertheless, a more practical and economical device. The award of the John Scott Legacy Premium and Medal is recommended. (*Sub-Committee*, Richard L. Humphrey, chairman; Richard Gilpin, H. S. Balliet.)

(No. 2308.) *Unhairing and Tanning Animal Skins by Electricity.* George D. Burton, Boston, Mass.

(An advisory report.)

(No. 2316.) *Reconstructed Milk.* Charles H. and Pearl T. Campbell, Bayonne, N. J.

ABSTRACT: This invention embraces a method of treating milk for the purpose of preserving it. It comprises two successive operations, the first of which concentrates the solid constituents of the milk in a partially or wholly dried condition, while the second reconverts it into its original form of natural milk.

The several processes involved herein are not susceptible of intelligible description without the aid of drawings.

The committee's conclusions are as follows: "The practical importance of a process of treating milk so that this almost indispensable product may be

effectively preserved in a dried state and eventually restored to a liquid form in a practically normal condition, is so obvious as to need no special elucidation. That this desideratum has been attained in the Campbell process of concentrating and remaking milk is being demonstrated in commercial practice." The award of the John Scott Legacy Premium and Medal is recommended to the inventors. (*Sub-Committee*, Louis E. Levy, chairman ; Harry F. Keller, William O. Griggs.)

(No. 2321.) *Alumino-Thermics.* Hans Goldschmidt, Essen, Germany.

This report relates to the inventions of Dr. Hans Goldschmidt, of Essen, in utilizing, by various means, the very high temperatures accompanying the chemical reaction of aluminum with certain metallic oxides, such as oxide of iron. (The report is reserved for publication in full.) The award of the Elliott Cresson Medal is made to the inventor. (*Sub-Committee*, H. F. Keller, chairman; Henry G. Morris, A. E. Outerbridge, Jr., G. H. Clamer, Victor Angerer, James Christie.)

(No. 2326.) *Feed-Water Regulator.* Amos E. Burrows, York, Pa.

ABSTRACT : The automatic steam-pump regulator is applied to a single boiler, and consists of a vertical cylindrical vessel of cast iron, which is placed in the water column of a boiler, and may have the usual gauge-glass and gauge-cocks attached to it. Within this cylindrical vessel is a copper float, with spindles on top and bottom, the upper spindle having a set of levers connected to it, to which is attached a small ball-valve in such a manner that the raising of the float will close the valve.

This valve being at the end of the feed-pump steam-pipe, its closing will stop the pump. The sinking of the water line, in lowering the float, carries the lever system attached to the float to open the valve, thus starting the feed-pump. One of the levers in the system is connected to a small whistle on top of the regulator, so that the sinking of the float to a certain distance admits steam to the whistle, sounding it.

The automatic feed-water regulator is similar in construction, having a cylinder in the water column, with a float. The top spindle of the latter, however, is only connected to the low-water alarm whistle, while the lower spindle works a set of levers, which open or close a valve in the feed-pipe by the lowering or raising of the float.

This regulator is applied to each boiler, where a number of boilers are fed by one pump, so that the feeding of each boiler is regulated by its own water level. When the feed valves to all boilers are shut, the pump is stopped by a diaphragm back-pressure valve attached to the steam pipe of the pump, the increased pressure in feed pipe—due to all feed pipes being shut—acting on the diaphragm so as to close the steam valve. A spiral spring with adjusting screw regulates the pressure at which the valve is to be closed.

The automatic steam pump regulator is covered by United States letters-patent No. 507,211, October 24, 1893, and the feed-water regulator by patent No. 618,981, February 7, 1899.

The report finds that these devices are extensively used in practice, and give entire satisfaction, exhibiting a considerable economy of fuel.

The award of the John Scott Legacy Premium and Medal is recommended to applicant. (*Sub-Committee*, John Haug, chairman; J. M. Emanuel, Chas. E. Ronaldson.

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Mining and Metallurgical Section.

Stated Meeting, held Thursday, February 4, 1904.

Change of Structure in the Solid State.

BY W. CAMPBELL, PH.D.,
Barnard Fellow, Columbia University.

Besides the changes which occur when a metal or alloy passes from the liquid to the solid state, there are those which take place after solidification.

(1) Change of structure due to mechanical stress and the growth of crystals on annealing the metal or alloy thus strained. This subject has been carefully studied by Ewing and Rosenhain * and others.

(2) Due to change in composition in the solid—diffusion. Under this heading we have carburization † (cementation, case-hardening, etc.): decarburization ‡ (and change of

* Phil. Trans. Royal Society, 195, p. 279, and 193, p. 353.

† Arnold. *Journal I. and S. Inst.*, II, 1898, p. 185.

‡ Stead. *Proc. Cleveland Inst. Eng.*, Dec., 1895, p. 79.

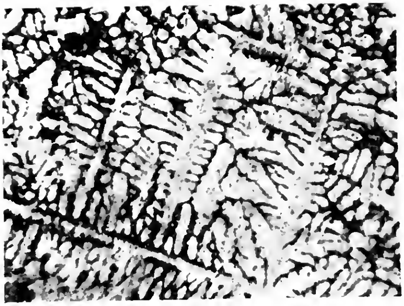

Fig. 1. × 35. V.

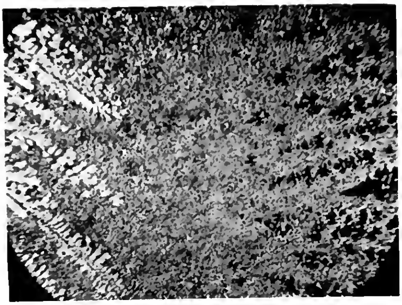

Fig. 2. × 20. V.

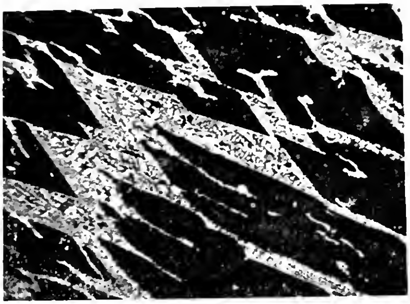

Fig. 3. × 30. O.

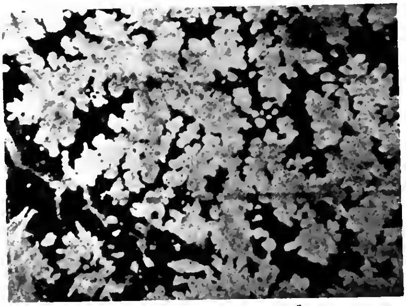

Fig. 4. × 35. V.

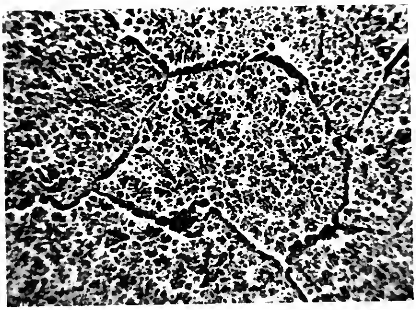

Fig. 5. × 16. V.

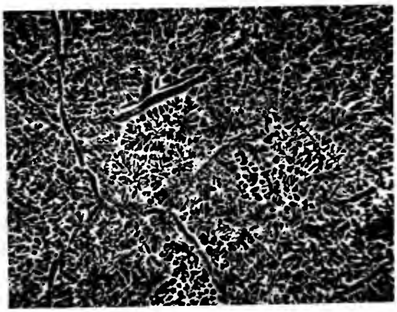

Fig. 6. × 35. V.

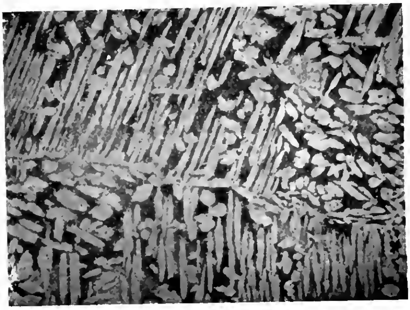

Fig. 7. × 35. V.

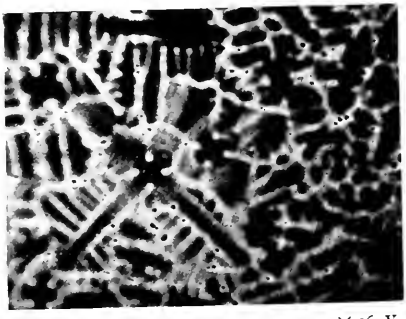

Fig. 8. × 16. V.

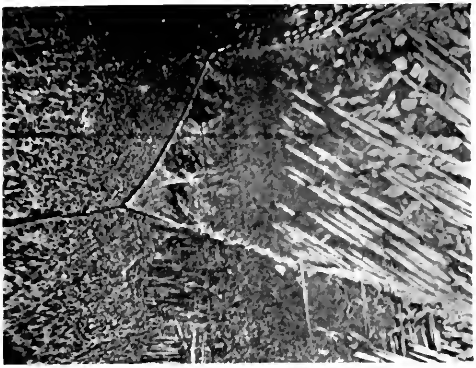

FIG. 9. 35. V.

FIG. 10. 35. V.

FIG. 11. × 33 V.

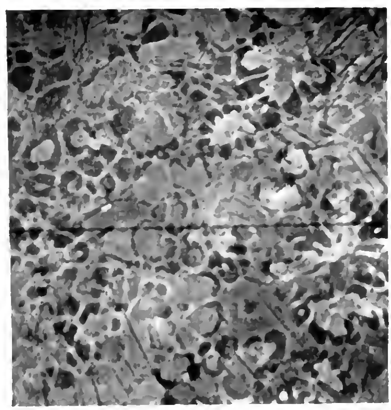

FIG. 12. 33. V.

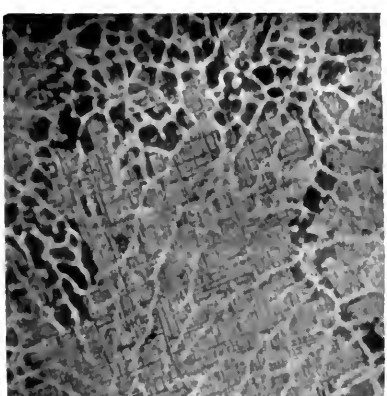

FIG. 13. 35. V.

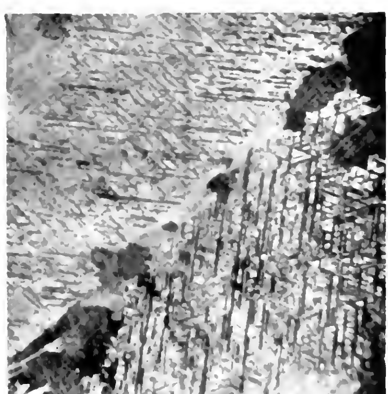

FIG. 14. 35. V.

carbon from the combined to the free state, or from cementite to graphite, *e. g.*, malleable cast iron): passage of one metal into another, as gold into lead:* oxidation, as the formation of alloys of copper and oxide of copper in the solid.†

(3) Changes which occur in the solid with change of temperature, such as the change of pure iron from one state or allotropic modification into another‡ (α, β and γ). *The change of structure in the solid state* which occurs when certain alloys cool down from their point of solidification to the normal temperature. Such changes are found in the alloys of copper and aluminum, of copper and tin, of copper and antimony, of iron and steel, etc.

Copper and Aluminum.—In the alloys of copper and aluminum, Le Chatelier has found at least three compounds, viz.: Al_2Cu, $AlCu$ and $AlCu_3$.

From pure aluminum to Al_2Cu we have a simple series, whose freezing-point curve is composed of two inclined branches, intersecting at the eutectic alloy (about 32 per cent. Cu). As we pass from the aluminum end to the alloy with 31 per cent. Cu, we find dendrites and grains of aluminum set in an increasing eutectic or groundmass, which freezes at about 530° C.

Fig. 1, magnified 35 diameters, vertically illuminated, shows the alloy containing 23 per cent. Cu, in which part of a large dendrite of aluminum is seen surrounded by the eutectic. This eutectic is seen in places to be composed almost entirely of Al_2Cu, because, during solidification, its aluminum has migrated to and merged with that composing the grains and dendrites. As Stead has pointed out, this is of common occurrence in many eutectics. It is specially marked in the case of the copper-rich or silver-rich alloys of the copper-silver series.

From 32 per cent. Cu to Al_2Cu, we find this compound crystallizing out in decreasing amounts of the eutectic.

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* Phil. Trans. Royal Society, 187 (1896), p. 383.

† Heyn. Inter. Ass. Test. Mat., 1901. (Hofman. T. A. I. M. E. 1903.)

‡ Osmond. "Annales des Mines," Jan., 1900. *Metallographist*, III, 181.

Fig. 3 × 30 diameters oblique illumination shows the 45 per cent. alloy, and may be taken as a type. The structure of the whole series is well shown in a diffusion alloy, made by pouring molten aluminum onto the molten compound, Al_2Cu, and allowing the whole to slowly solidify. *Fig. 2* × 20 V represents the junction between the two. (The top of the alloy is on the left hand of the photomicrograph.) We see dendrites of aluminum growing down into the eutectic alloy, whilst crystals and dendrites of the compound Al_2Cu grow upwards.

When the copper in the alloy is increased above Al_2Cu, the second compound AlCu is found crystallizing out in a groundmass of the first. *Fig. 4* × 35 V shows this structure. The alloy contains 66 per cent. copper, 34 per cent. aluminum. With further increase in copper, the alloys are apparently homogeneous from 78 to above 83 per cent. Cu. Above this point to about 90 per cent. Cu, we find structures in the slowly cooled alloys due to a rearrangement in the solid. *Fig 5* × 16 V is the alloy containing about 85 per cent. Cu, in which dark veins and irregular grains are surrounded by a lighter envelope. If the alloy be raised to a red heat and quenched, a change in structure occurs, and under a low power (33 diameters) the alloy is apparently homogeneous, though with a higher magnification it is seen to be composed of alternate light and dark bodies. On reheating to a red and slowly cooling, the original structure is restored. *Fig. 6* × 35 V shows the same alloy quenched, then reheated and slowly cooled. The structure of *Fig. 5* has been reproduced. As the copper is again increased, the dark constituent disappears, leaving the light body which, under high powers, is seen to possess a eutectic structure. With further additions of copper, bright grains and veins of $AlCu_3$ make their appearance. *Fig. 7* × 35 V shows the 89 per cent. Cu alloy and consists of bright $AlCu_3$ set in a darker groundmass with the eutectic structure. Again, the structure of the series can be well shown by a diffusion alloy between 80 and 90 per cent. copper. Such an alloy is seen in *Fig. 9* × 35 V. (The top of the figure is on the left.) Dark dendrites, similar to those in *Fig. 5*, are seen to grow downwards,

whilst the bright $AlCu_3$ grows upwards. The central zone is composed of the alloy having the fine eutectic structure. Between this and the upper part of the alloy, a third constituent sometimes occurs, as long bright needles, etc., but as yet it has not been isolated. Now if the alloy shown in *Fig. 9* be reheated to a red and quenched, the whole mass becomes homogeneous and has the structure seen in *Fig. 10*. This structure closely resembles that of steel quenched from a very high temperature (martensite). On reheating and slowly cooling, the original structure is restored. Although the complete cooling curves for these alloys have not yet been published, there is no doubt that the alloys solidify as homogeneous solid solutions resembling martensite, and at a lower temperature rearrange themselves as shown in *Fig. 9*. The curve due to this rearrangement in the solid will therefore be similar to that of a simple series of alloys forming neither solid solutions nor isomorphous mixtures.

From 92 per cent. Cu onwards, we find the alloys consist of solid solutions (probably of $AlCu_3$ and Cu). *Fig. 8* $\times$ 16 V shows the alloy containing 97 per cent. Cu slowly cooled. The copper dendrites are seen to vary in composition from center to outside, and in this they resemble those at the copper end of the CuSn series. It may be, however, that we are not dealing with a compound $AlCu_3$, but with a series of solid solutions whose maximum composition corresponds to $AlCu_3$.

Copper and Tin.—The constitution of the alloys of copper and tin has been carefully worked out by Heycock and Neville.* *Fig. 33* is based on their curve. In a former paper † the structure of the series was shortly set forth, but several points were left open to discussion, because the exact meaning of many of the changes which take place in the solid were not known, my own investigations ‡ only explaining some of them.

The curve *A B L C D E G H I K* marks the beginning of crystallization and above this freezing-point curve the alloys

* Bakerian Lecture. *Phil. Trans. R. S.*, Vol. CCII, A., pp. 1–69.

† *Jour. Frank. Inst.*, July–Sept., 1902.

‡ *Proc. Inst. Mech. Eng.* (London), Dec., 1901, pp. 1211–1272.

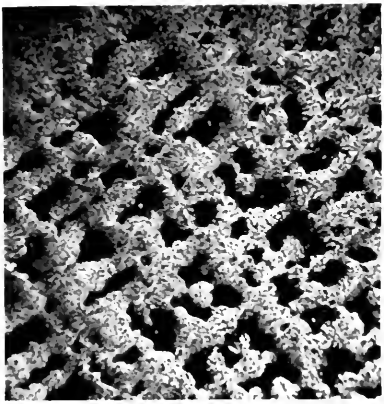

FIG. 15 55. V

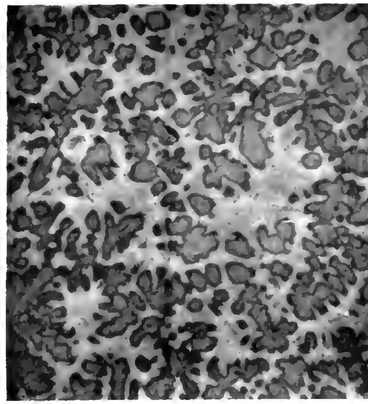

FIG. 16. 35. V.

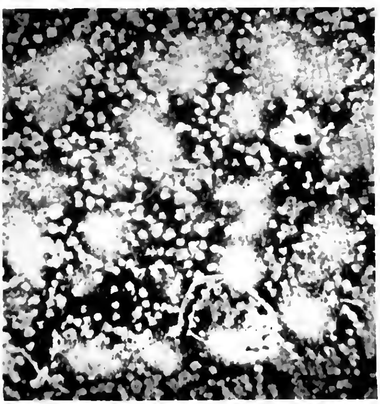

FIG. 17. 33. V.

FIG. 18 88. V.

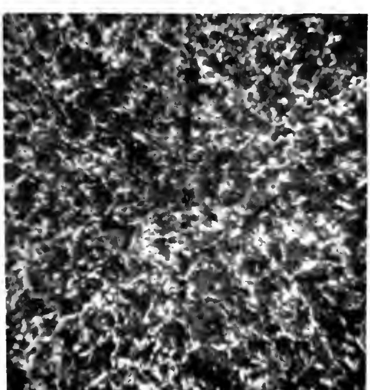

FIG. 19. 120.

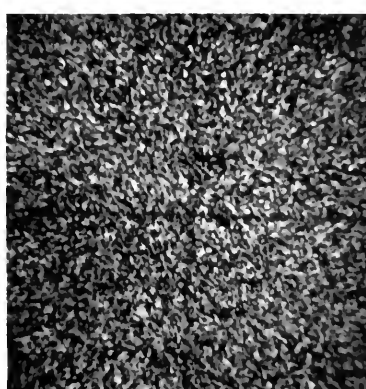

FIG. 20. 120.

are in the liquid state. Professor Rooseboom calls a curve of this kind the "liquidus." Below the curve *A b l c m d e f*-$E_2 E_3 H' H'' K'$ everything is solid, this being termed the "solidus." Between the two we have a mixture of the solid and liquid states, whose compositions are given by a horizontal line cutting the liquidus and solidus. The horizontal line marks the temperature at which these two phases (liquid and solid) are in equilibrium. Heycock and Neville divide the series into ten groups marked by the points *B, L, C, D, E, F, G, H* and *I*.

(1) The alloys occurring between *A* and *B* (100 to 91 per cent. Cu) consist of a uniform solid solution of up to 9 per cent. tin in copper (α) below *A b*. Between the liquidus and solidus, they consist of crystals of α + a liquid richer in tin. In the moderately slowly cooled alloys, it is often found that the central parts of the dendrites of α etch differently from the outsides, due to their being richer in copper, and cooling not being slow enough to allow of perfect diffusion to produce uniform composition. Such a structure is seen in *Fig. 8*.

(2) The alloys from 91 to 77·5 per cent. copper or *B* to *L* on passing the liquidus begin to crystallize out dendrites of α; but on reaching the temperature marked by the line *b l C* they react with the mother liquor:

α (of composition *b*) + liquid (of composition *C*) = β (of composition *l*) until the whole of it is used up. The substance β is a solid solution containing from 22·5 to 27 per cent. tin. Below *b l*, or 790° C., the whole mass is solid, and consists of dendrites of copper containing about 9 per cent. tin in solid solution (α_b) surrounded by a solid solution of composition 77·5 per cent. Cu, 22·5 per cent. Sn (β_l). As the temperature falls from 790° C. (*b l*) to 500° C. (*b' C'*) the dendrites of α continue to grow at the expense of the solid solution β, whose composition is reduced from 77·5 to 74·5 per cent. Cu. On *b' C'* the residual β breaks up into minute α and Cu_4Sn (δ). In other words, at the temperature *b' C'* (500° C.) the remaining solid solution β is transformed into the eutectoid of copper (containing tin in solid solution) and the compound Cu_4Sn, which is the structure found at the normal temperatures.

(3) The alloys from 77·5 per cent. to 74·5 per cent. copper, or L to C, on reaching the liquidus begin to separate dendrites and grains of a, but the whole of this is changed into β containing l per cent. of copper on reaching the temperature marked by $l\ C$. The dendrites, etc., of this solid solution β continue to grow, their composition and that of the liquid being given by the solidus $l\ c$ and the liquidus $C\ D$ as before, until the whole is a solid solution below $l\ c$. On reaching the temperature of the curve $l\ C'$, however, the solid solution β becomes saturated with a, which crystallizes out as in the alloys under (2). Then when the temperature marked by the line $b'\ C'$ is reached, the remaining β is resolved into the eutectoid of a and δ or copper (with tin in solid solution) and Cu_4Sn.

(4) The alloys from 74·5 per cent. to 68·2 per cent. copper comprise the series from C to D, or from the eutectoid to the compound Cu_4Sn. On reaching the liquidus $C\ D$ they separate out the solid solution β, but when less than c per cent. copper is present they are changed into the solid solution γ on reaching the temperature $c\ m\ D$. Below the solidus the whole mass is a solid solution, until the temperature of the curve $D'X$ is reached, when the compound Cu_4Sn or δ separates out as veins and irregular grains or rosettes. The compound continues to separate out until the temperature $X\ D_2$ is reached, when the remaining solid solution splits up into the eutectoid of $a + \delta$ as before.

As Heycock and Neville have pointed out,* the surfaces of these alloys are covered with large dendrites due to the initial crystallization. If the surface is polished, it is at once seen that they have re-arranged themselves, and are now built up of the compound Cu_4Sn and the eutectoid. *Fig. 15* × 55 V shows such a polished surface in the alloy containing 73 per cent. copper, in which the composite nature of the primary crystallization is seen. *Fig. 16* × 35 V shows the same alloy quenched at the solidification point, and shows the dark dendrites of the solid solution β set in the lighter groundmass richer in tin. *Fig. 17* × 33 V

* *Proc. Royal Society*, Vol. XCVI.

shows the same alloy slowly cooled to 650° C. and quenched. The alloy is not homogeneous throughout, but parts have been resolved into a light and dark constituent. It may be that we have a partial separation of the compound Cu_4Sn due to the quenching being too slow. *Fig. 18* × 88 V shows the very slowly cooled alloy in which the bright Cu_4Sn has separated out of the solid solution as veins and rosettes, whilst under a higher power the darker groundmass is seen to be composed of the eutectoid.

(5) The alloys from 68·2 per cent. to 61·6 per cent. copper, or from D to E, pass from the compound Cu_4Sn to the compound Cu_3Sn. On reaching the curve $D\ E$, dendrites of the solid solution γ crystallize out until the whole mass is solid. When the temperature reaches the curve $E'\ D'$, the compound Cu_3Sn separates out (η) until at the temperature $D'\ E''$ the residual γ has the composition of 68·2 per cent. Cu, when it is transformed into δ, or the compound Cu_4Sn. *Fig. 12* × 33 V shows the alloy containing 66 per cent. Cu 34 per cent. Sn quenched just before solidification, and is composed of cells of the solid solution γ. *Fig. 13* × 35 V shows the same alloy quenched on the solidus, and is composed of almost uniform γ. *Fig. 14* × 35 V shows the alloy quenched between the solidus and $E'\ D'$. All trace of the cell-like structure has gone, and we have large grains of γ, with a curious linear structure (seen also in *Fig. 13*), due perhaps to the difficulty in preventing the beginning of the change on $D'\ E'$ or to the nature of γ itself. *Fig. 11* × 33 V shows the alloy slowly cooled, and consists of dark bands of Cu_3Sn or η surrounded by the lighter $SnCu_4$ or δ. The compound η separated out on reaching the temperature of the curve $D'\ E$, whilst the residual solid solution γ changed over into the bright Cu_4Sn on reaching $D'\ E''$.

(6) The alloys between 61·6 per cent. and 59 per cent. copper, or E to F, are very remarkable. To quote Heycock and Neville: "These go through the same stages of γ + liquid, then homogeneous γ, then $\gamma + \eta$; but when the temperature of the line $f\ G$ is reached, the residual γ breaks up into η and liquid of the composition G. Thus these alloys present the somewhat rare phenomenon of the partial melt-

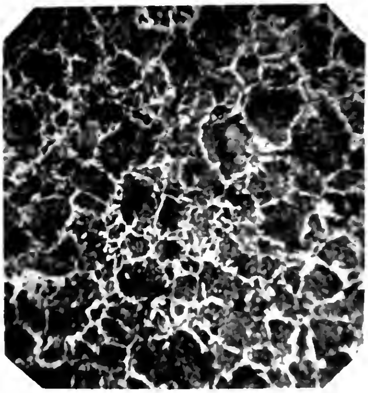

FIG. 21. 120.

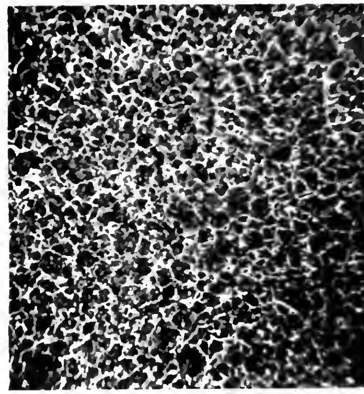

FIG. 22. 33. V.

FIG. 23. 33. V.

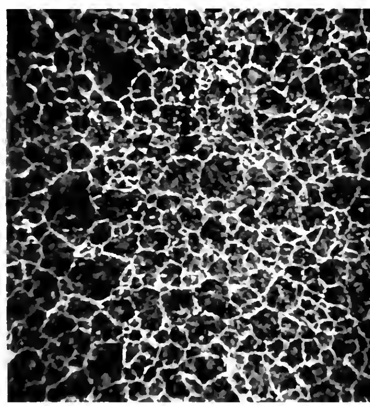

FIG. 24. 33. V.

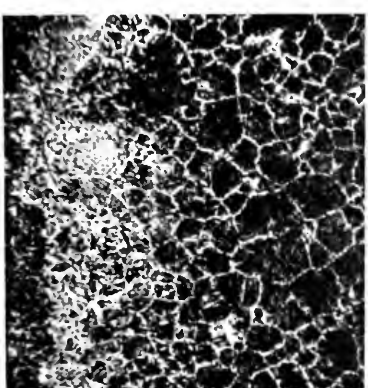

FIG. 25. 33. V.

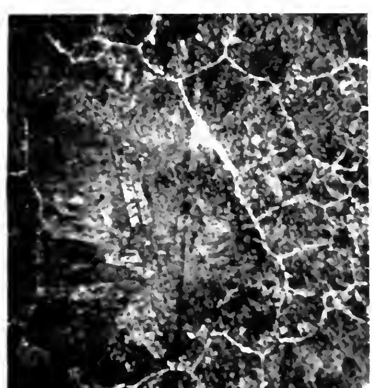

FIG. 26. 33. V.

ing of a solid brought about by cooling it. The transformation $\gamma_f = \eta_{E'} +$ liquid$_G$, or as we may safely write it, $\gamma_f =$ Cu_3Sn + liquid$_G$, is the transformation which causes the angle at G in the liquidus."

(7) The alloys between 59 per cent. and 42·5 per cent. copper, or F to G, act as the above, and when cooled below the temperature E_2 G (630° C.) continue to separate out Cu_3Sn and thus enrich the liquid portion of the alloy in tin, whilst below the temperature E_3 H, or 400° C., they behave as the next series.

(8) The alloys from 42·5 per cent. to 7 per cent. copper begin to separate out the compound Cu_3Sn on reaching the liquidus G to H, and the liquid alloy is enriched in tin until it has the composition H. At this temperature E_3 H (400° C.) the compound Cu_3Sn is no longer in equilibrium with the remaining liquid, but reacts with it, and we get the compound H (approximately CuSn) formed. The reaction does not go far enough to produce complete equilibrium by changing the whole of the liquid on the left of H' and the whole of the CuSn or H on the right of H', because the crystals of the compound Cu_3Sn soon become covered by an envelope of H, which prevents further action except by diffusion. Hence a third phase is found in each case, which is enclosed by a bracket to denote it ought not to exist if the change had been complete. By keeping the alloys for several days at a temperature just below E_3 H, Heycock and Neville have succeeded in establishing equilibrium and producing two phases. As the temperature passes the line E_4 I K', the liquid, which has the composition I (about 1 per cent. copper), due to further separation of the solid H, as in the next group, solidifies as the eutectic of tin and H.

(9) Between H and I, or 7 per cent. to 1 per cent. copper, the solid H (approximately CuSn) separates out on passing the liquidus and enriches the mother-liquid in tin until, at the temperature M I, it has the composition of about 1 per cent. Cu, when it solidifies as the eutectic as before.

Lastly, the alloys containing 1 to 0 per cent. copper separate out grains and dendrites of tin on reaching the liquidus I K, whilst at the temperature I K' the remaining liquid (1 per cent. Cu) solidifies as the eutectic of tin and CuSn.

The above is a short account of the changes which occur during and after solidification in the alloys of copper and tin. The Bakerian Lecture by Heycock and Neville, "On the Constitution of the Copper-Tin Series of Alloys," is by far the best piece of work upon this subject, and is illustrated by over 100 beautiful photomicrographs which will well repay the reader.

Iron and Carbon.—The alloys of iron and carbon, due to their great importance, have been studied more than any other series. Their constitution is represented by the diagram in *Fig. 34*, which is based upon that of Professor Rooseboom.*

The freezing-point curve or liquidus is represented by *A B D*, whilst below the solidus *A a B C* everything is solid. The branch *A B* marks the commencement of solidification. Dendrites of martensite separate out and contain a maximum of about 2 per cent. carbon in solid solution. In alloys containing more than 2 per cent. carbon the martensite-graphite eutectic makes its appearance. The horizontal line *a B C* marks the evolution of heat due to its solidification. The branch *B D* corresponds to the separation of free graphite. Hence we find from 0 to 2 per cent. carbon the alloys solidify as dendrites of martensite; from 2 to 4·3 per cent. carbon or *a* to *B*, the alloys solidify as dendrites of martensite set in the groundmass or eutectic of graphite and martensite. Alloys having the composition *B* solidify as the eutectic and contain neither free martensite nor free graphite, whilst above *B* or 4·3 per cent. carbon we have free graphite (as kish) and the eutectic.

As the temperature falls from *a B C* to *E F H*, or about 1,000° C., the martensite becomes supersaturated with graphite, which separates out along the line *a E*, reducing the total carbon in solid solution to about 1·8 per cent. At the temperature *E F H* a transformation occurs. The martensite is no longer in equilibrium with graphite but reacts with it.

Martensite (1·8 per cent. C) + Graphite = Cementite (Fe_3C).

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* *Zeits. f. Phys. Chem.*, XXXIV, 1900, p. 437.

This reaction is very slow and in ordinary cooling only goes a short way, and hence we find graphite below *E F H* due to lag.

As the temperature falls below 1,000° C., the martensite becomes supersaturated with carbon, which separates out as cementite (Fe_3C) along the curve *E S* until at the temperature *S*, or just under 700° C., recalescence occurs and the residual martensite, containing about 0·8 per cent. carbon, is transformed into the eutectoid pearlite, consisting of alternate laminæ of cementite and ferrite (or pure iron).

In the case of white irons, solidification commences, as before, by the separation of dendrites of martensite, but the mother-liquid solidifies as a eutectic of martensite and cementite, on the line *E′ B′ F′*. This must take place because martensite and graphite are not in equilibrium, and the difference between this and gray irons is probably due to the difference in the amount of silicon, manganese and other impurities present. On further cooling the martensite is transformed in the solid as before.

Coming next to the series containing 0 to 1·8 per cent. carbon. Above the temperatures marked by the curve *G O S E*, they exist as the solid solution martensite, but as the temperature falls transformations occur.

In the case of alloys containing up to *S* or 0·8 per cent. carbon, as the temperature reaches the curve *G O S* the martensite becomes supersaturated with ferrite, which separates out and enriches the martensite in carbon until it contains *S* or 0·8 per cent. at just under 700° C. At this point recalescence occurs and the residual martensite is transformed to the eutectoid pearlite. Hence within the area *G O S P* we have ferrite and martensite, whilst below *P S* we have ferrite and pearlite. The steel containing *S* or 0·8 per cent. carbon exists as martensite until the temperature *S* is reached, when it is transformed into pearlite as before. The alloys containing 0·8 to 1·8 per cent. carbon become supersaturated with cementite, which separates out along the curve *E S* and reduces the carbon in solid solution to *S* or 0·8 per cent. at just under 700° C., when the residual martensite is transformed to pearlite as before. Hence, between

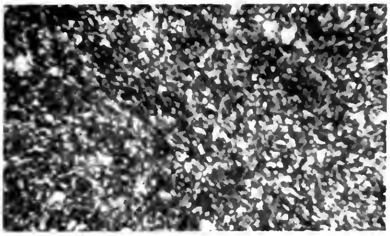

FIG. 27. 120.

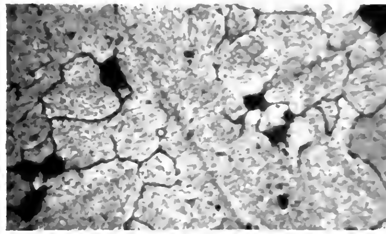

FIG. 28. 120.

FIG. 29. 120.

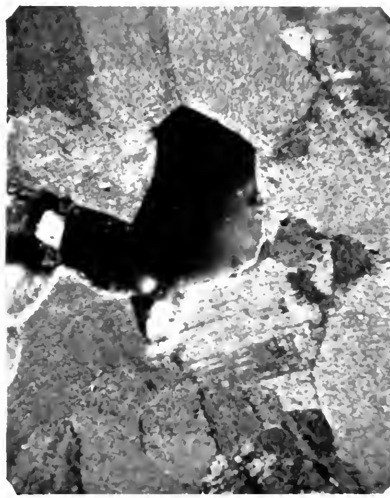

FIG. 30. 33.

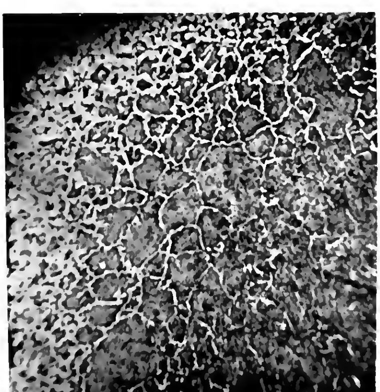

FIG. 31. 33. V

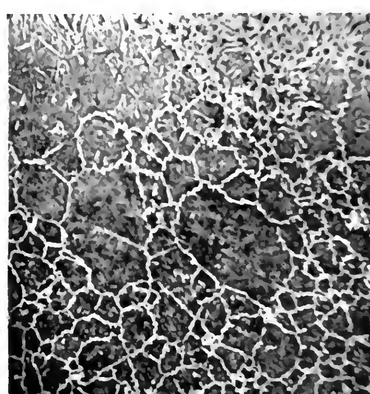

FIG. 32. 33. V

the temperatures *E S* and *P S K*, we have cementite and martensite, whilst below the temperature *S K* we have cementite and pearlite.

Another change occurs with fall of temperature. Iron has three allotropic modifications, viz., α, β and γ. The γ form exists above the temperature *G O S*, the β form within the area *G O M*, whilst the α modification occurs below *M O S*. The evolution of heat *M O* is due to the transformation of β into α iron with the regain of magnetism.

These changes in the solid are of the utmost importance, because upon them depend hardening, refining and the like. Sauveur,* in a paper on "The Relation between the Structure of Steel and its Thermal and Mechanical Treatment," gives a very clear account of the changes which occur. Stead† has shown the effects of heating bars of from 0·013 to 1·14 per cent. carbon to various temperatures, whilst Arnold‡ has done much work along the same line.

The following will give some idea of the great changes which occur with heat and mechanical treatment. A steel containing 0·50 per cent. carbon and 0·98 per cent. manganese gave two critical points on heating. Ac_1 at about 700° to 710° C. very marked, and $Ac_{2\cdot3}$ at about 745° to 750° C. very slight. On cooling, $Ar_{2\cdot3}$ was slight at about 700° C., whilst Ar_1, the recalescence point, was very strong at 660° C. The effect of slowly heating to given temperatures and cooling in air and quenching in water was determined by physical tests and by microstructure. The material was $\frac{7}{16}$ inch square.

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* *Journal Iron and Steel Institute*, II, 1899, p. 195. (Also see *T. A. I. M. E.*, 1896.)

† *Journal Iron and Steel Institute*, I, 1898.

‡ *Jour. Iron and Steel Institute.*

The following table gives the results of physical tests:

	COOLED IN AIR.				QUENCHED IN WATER.			
Bar heated to	Elastic L., lbs. per sq. in.	Maximum Load, lbs. per sq. in.	Elongation in 8 inches.	Reduction of Area.	Elastic L., lbs. per sq. in.	Maximum Load, lbs. per sq. in.	Elongation in 8 inches.	Reduction of Area.
Degrees C.								
659	72,500	102,900	15·6	55·7	67,000	107,150	15·2	50·2
682	67,100	104,100	17·5	50·8	64,000	107,400	15·6	55·3
700	62,500	101,250	17·6	53·1	63,000	127,800	—	8·5
702	62,400	100,400	14·3	55·8	61,250	133,500	—	2·2
718	63,700	102,300	17·4	54·3	—	188,900	—	—
733	65,600	108,400	17·4	52	71,100	203,100	—	—
746	75,200	112,000	16·25	51·5	—	135,050	—	0·3
766	74,600	112,600	16·5	42·8	60,900	103,800	—	0·1
775	74,600	112,200	—	50·6	—	104,000	—	0·1
819	73,600	115,950	15	48·4	—	60,100	—	—
843	73,100	117,100	15·6	46	—	39,000	—	0·4
902	71,400	115,000	11·87	41	—	80,500	—	—
966	69,700	114,800	13·6	42·7	—	72,300	—	0·5
1030	67,000	110,300	14	38·4	—	45,750	—	—
1086	66,400	108,800	12·1	39·3	—	61,050	—	0·2
1151	66,100	109,950	8·1	34·4	—	61,300	—	—
1212	64,900	108,400	11·25	32·2	—	70,200	—	0·2
1268	66,900	112,800	8·1	12·7	—	54,900	—	—
1339	65,400	113,900	5·5	7·6	—	56,800	—	—
1390	60,700	98,200	3·4	5·4	—	61,800	—	0·6
Original	70,550	113,400	13·9	46·4				

Steel Cooled in Air.—From the above it will be seen that re-heating to the lower critical point lowers the elastic limit and maximum load uniformly, whilst from this point to the upper point $AC_{2\cdot3}$ there is an improvement until we return to almost what we started with. The best elastic limit occurs just at this point, whilst the greatest maximum load occurs about 840° C. The elongation shows a marked improvement to a little below the upper critical point, after

which there is a regular falling off until at 1,390° C. the steel is very much overheated. The reduction of aka is greatest at Ac_1, and falls off with higher temperatures until reduced to 5½ per cent. at 1,390° C.

On examining the microstructure, the original steel, shown in *Fig. 19* × 120, consists of medium-sized grains of dark pearlite surrounded by veins of ferrite. Above 700° C. these grains are reduced in size until we get the finest structure at 733° C. or just below $Ac_{2\cdot3}$. This is shown in *Fig. 27* × 120, which is the bar heated to 733° C. and slowly cooled in air. With increase in temperature, we get an increase in the size of structure. *Fig. 21* × 120 shows the bar heated 819° C., and the structure is much larger than that of the original steel. There is a better separation of the ferrite, the pearlite being less unsegregated. *Fig. 22* × 33 V shows the bar heated to 966° C., whilst *Fig. 23* × 33 V is the bar heated to 1,086° C. with a proportionate growth of grain. The photograph is taken at the edge of the section to show the very distinct decarburization of the outer layer. *Fig. 24* × 33 V shows the steel heated to 1,151° C., and *Fig. 25* × 33 V is that heated to 1,212° C., the photograph being again taken from the edge to show decarburization. The structure has become very coarse indeed. *Fig. 26* × 33 V shows the steel heated to 1,339° C. The crystals have grown to an enormous size, whilst in the center of the largest a new structure is seen, which may be a relic of the old martensite which was not completely transformed on passing Ar_1. We have evidently reached the point where we get great overheating.

In considering the changes which have taken place on re-heating, we know that the *pearlite* will give the finest structure when the steel has been heated to just above Ac_1, or when it has been transformed to martensite. Heating above this point will cause a growth of structure, the higher the temperature the coarser the structure. The *ferrite* begins to diminish in size above Ac_1, because the martensite commences to dissolve it. This will continue until the whole of it has disappeared, when the change Ac_{2-3} is complete. Now, the *whole steel* will have the finest

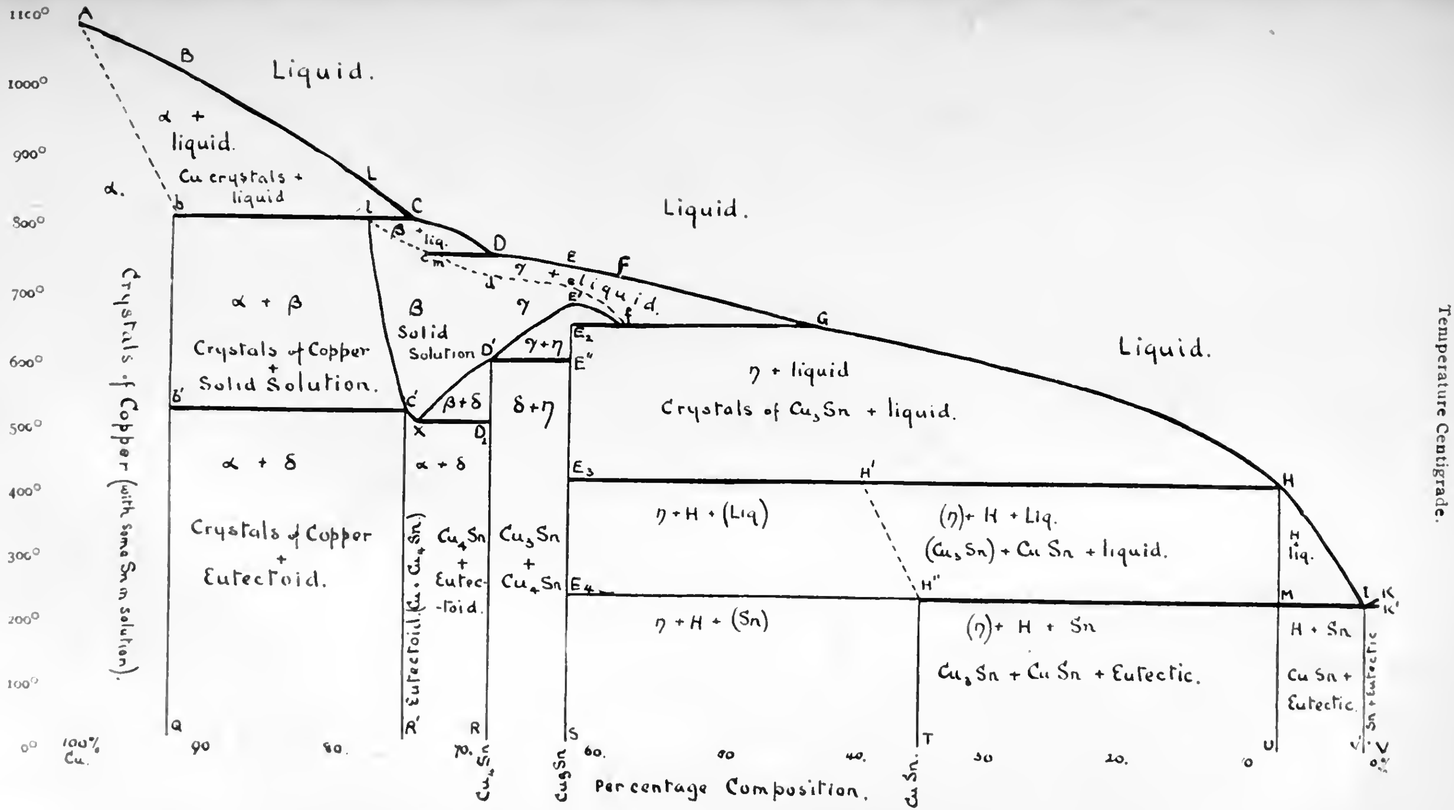


FIG. 33.—Equilibrium curve: copper-tin series.

structure where these two changes balance, which is apparently just below Ac_{2-3}. Thus we find the steel heated to 733° C. has the finest structure, and in *Fig. 27* this is shown.

Steel Quenched in Water at about 15° C.—On looking at the physical properties of the quenched bars, we see that at the lower critical point Ac_1 hardening takes place and the reduction of area falls to 8·5 per cent. The maximum load runs up at this point also, and reaches a maximum at 733° C. of almost twice the original. Heating to above this point causes a rapid falling off. (The great difficulty experienced with the hardened bars to get them quenched straight, constant breaking in the grips of the testing machine, etc., accounts for the poor results in the table.)

Under the microscope, we see no marked effect from quenching below the lower critical point. The bar quenched from 700° C. (Ac_1) showed a great change. The groundmass is no longer pearlite, but is now hard martensite. Hence the falling off in the reduction of area. *Fig. 20* × 120 shows the steel quenched from 733° C. It has the highest maximum load and also the finest structure. The ferrite has been nearly all absorbed. Under high powers two constituents are seen: the one is hard and but lightly attacked by the etching fluid (2 per cent. nitric acid, 1·4 specific gravity in alcohol), whilst the other is turned black. These two are martensite and probably the transition form tröostite.

Bars quenched from above Ac_{2-3} consist entirely of martensite. The size and shape of the martensite grains (which, of course, increase with the temperature to which the bars have been heated) can be seen on grinding down a fractured surface. *Fig. 28* × 120 shows such a surface from the steel quenched from 900° C., in which the course of fracture is seen between the grains of martensite. *Fig. 29* × 120 shows a section of the bar quenched from 1,212° C. The structure of the martensite is now coarse enough to be seen with this magnification, and is characterized by a series of light and dark bands in three directions usually, forming triangular markings. Lastly, in *Fig. 30* × 33, we have a polished fracture of the bar heated to 1,390° C. and quenched. The

martensite crystals have grown to an enormous size, and in section are bounded by more or less straight lines. The overheating has evidently been very great.

Heat Refining.—Supposing we have a quantity of the above steel, which has cooled down slowly from 1,390° C., it is very much overheated, and it is required to refine it, to what temperature must we re-heat it to obtain the best results? The answer can be seen from the table of heat treatment and the microstructure of the bars cooled in air. We shall find that re-heating to that point where the changes due to Ac_1 and Ac_{2-3} just balance, will give the best results, for here we have the finest structure as before.

Mechanical Refining.—If, on the other hand, we have our steel at a high heat, it is cooling in the furnace from 1,390° C., and we wish to know at what temperature we have to roll it, or rather finish rolling it, to obtain the best results; if rolling be sufficient to break up the structure produced by the high temperature 1,390° C., then the final structure will depend on the growth of grain in cooling from the finishing temperature to Ar_1.

In a series of experiments, in which the bars were heated to 1,390° C., slowly cooled to certain temperatures and rolled, the reduction in area was 30 per cent. in two passes. The results are given in the following table:

Bar rolled at — Degrees C.	Elastic L., lbs. per. sq. in.	Maximum Load, lbs. per sq. in	Elongation in 8 inches.	Reduction of Area.
963	86,050	126,800	9·6	28·0
909	86,800	127,300	10·25	27·0
837	84,400	128,400	10·25	29·3
809	84,700	126,000	10·75	33·1
781	87,700	126,500	10·0	33·3
752	95,100	130,000	8·0	39·0
724	89,400	124,200	9·4	41·3
695	94,700	129,100	9·75	29·6
667	98,050	130,200	8·75	27·3
Not rolled.	60,700	98,200	3·4	5·4
Original.	70,550	113,400	13·9	46·4

On examining the results of physical tests it is seen that the elastic limit shows a great increase throughout. The maximum load has also passed that of the original and is greatest at the lowest rolling temperature. The elongation has been raised from 3·4 per cent. in the bars cooled in air from 1,390° C. to an average of 9·5 per cent., and is very fair when compared with that of the original steel, viz., 13·9 per cent. The reduction of area shows the more marked varia-

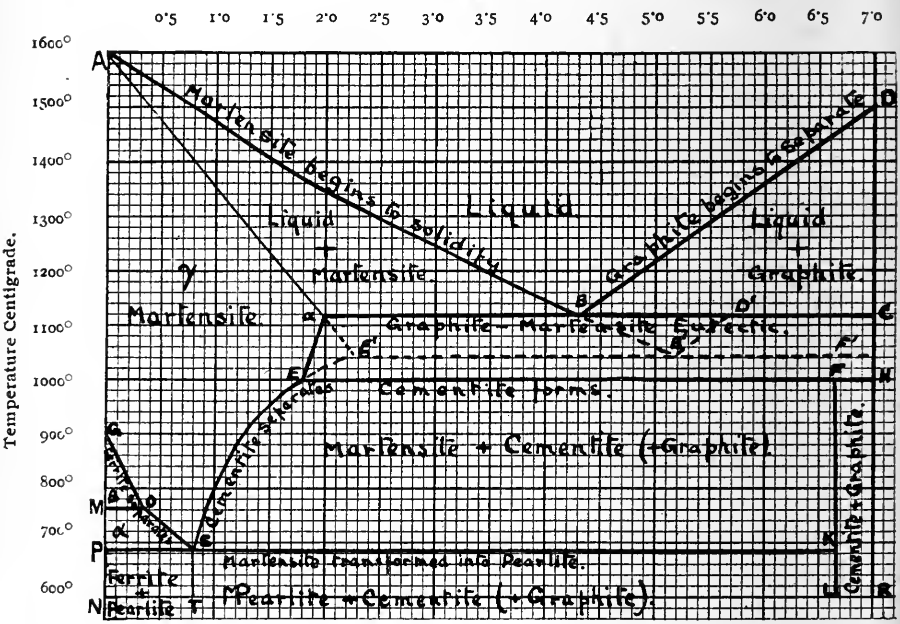


Fig. 34.—Equilibrium curve: iron carbon series.

tion. The bars heated to 1,390° and rolled at 752° and 724° C., respectively, show the best reduction—39 and 41·3 per cent. This is good, when compared with the unrolled bars and with the original with 5·4 and 46·4 per cent., respectively.

On examining the microstructure we find that the lower the rolling temperature the finer the grain, down to the bar rolled at 724° C., below which there is apparently a slight increase in size. In each case there has been more or less decarburization of the outside layer. In the bar rolled at

the highest temperature we have the largest grain, but this is very small when compared with that of the overheated bar. The ferrite has separated out as thin veins round the grains of pearlite, and also in them as irregular patches. With the lowering of the rolling temperature, we find little difference in the ferrite except that the veins are smaller because they follow the grain, and there is less free ferrite within the grain itself. On reaching the bar rolled at 724° C., a marked change is noticed. The ferrite veins round the outside of the specimen begin to thicken very much. This is seen in *Fig. 31* × 33 V, which shows the corner of this bar. The decarburized layer is seen on the top and left, whilst just within this zone a thickening of the ferrite is seen. This shows that the outer layer had reached the upper critical temperature before work had ceased. This is the steel which has been most refined. Below this we find that the thickening of the ferrite veins occurs right through the steel, or rolling was finished whilst the whole was below Ar_{2-3}. The bar rolled at 667° C., the lowest temperature, is shown in *Fig. 32* × 33 V. The coarsening of the ferrite walls is seen throughout the section. The top is near the edge and we have decarburization as before, but here we probably have the traces of cold rolling, for under high powers the ferrite has separated out as flattened forms and the pearlite is often abnormally coarse.

Although no rule can be drawn from one series of experiments, it is evident that, with the methods used, the best finishing temperature is such that the bars leave the rolls as near Ar_{2-3} as possible. The bars would of course have to be drawn from the furnace at a slightly higher temperature, to allow for cooling in the rolls. Making an allowance of say 40°, the rolling temperature would be about 740° C. This agrees with the experimental results shown in the table, for the two bars rolled at 752° and 724° C., respectively, gave the best results. The reason why the bar rolled at 667° C. does not show more traces of cold-rolling is because of the great evolution of heat at the recalescence point.

From the above examples are seen the great changes which occur, not only in iron and steel, but also in other

alloys, and cause a more or less complete rearrangement of structure. As the physical properties vary with the structure, great stress must be laid upon these changes in the solid, and our study of the effects of heat treatment must accompany that of microstructure, because the two go hand-in-hand and help to interpret each other.

THE EMPTY CAR HAUL.

The bane of railroad operation is the empty car haul, and to its reduction the best efforts of the transportation department are being constantly put forth. It is realized that the movement cost of each ton is the same whether it is embodied in the car itself or in its contents, and when it is considered that from 30 to 40 per cent. of the total tonnage moved by railroads consists of empty car haul, the importance of the question is easily understood. In view, therefore, of the magnitude of the subject and the part that it plays in operating expenses, it seems a little strange that a car of general utility, that is to say, one which could be used for two or more special commodities, has not yet been evolved. A number of attempts have been made to provide a car which would answer for both live stock and merchandise, but that appears to be impossible in the nature of things. A car suitable for joint use in coal and live stock traffic, or in coal and merchandise traffic, would seem to be more nearly possible, and we understand efforts are now being made in both of these directions. There is certainly enough to be gained by the production of a successful car of this character to warrant the devotion of the time and energy for its production.—*Railway Age.*

PHOTOLINOL.

Some interesting demonstrations have been carried out in London with a new photographic art material called "photolinol." This fabric is composed of linen, which is thoroughly permeated with the photograph, producing a high translucency. One very picturesque effect obtained by this means is that the picture, when colored and viewed with a reflected light, bears a very strong resemblance to an oil-painting, the lines of the weaving of the linen appearing similar to the canvas in a painting. Photolinol is waterproof and indestructible, while the photograph does not fade in the sun, as it appears to be woven into the material. By its aid much greater enlargements than are now possible can be made with ease. The fabric can be made to any size, some of the enlargements shown being 10 feet square. It is applicable to an extensive variety of purposes. As it is transparent, it can be adapted to lamp shades and other ramifications of photographic art for which transparencies are now employed. Novel results can be obtained with it, for the picture appears with equal distinctness on either side by either reflected or transmitted light. The process is a secret one, but its commercial utility and value are already asserted, since it can be employed for curtains, screens or theatrical scenery. For the latter it is peculiarly adapted, and is both cheaper and more durable than hand-painted scenery.—*Scientific American.*

ELECTRICAL SECTION.

Stated Meeting, held Thursday, March 3, 1904.

Circuit-Breakers.

By W. M. Scott.

The topic which has been assigned for this evening's discussion is one of such breadth that I will confine my discussion to but a single type of circuit-breaking apparatus, the "Reverse Current" Circuit Breaker, and will dwell more particularly on the form of this device which has been developed by the company with which I am associated, and who have for some years past been closely identified with the development of the "Reverse Current" circuit breaker.

A "Reverse Current" circuit breaker, or, as it is sometimes very aptly called, a "Discriminating Cut-out," is a circuit breaker which automatically severs the circuit in the event of the flow of current being abnormal in direction, and which, unless interrupted, would result in misapplication of energy. The "Reverse Current" circuit breaker most perfectly adapted to the requirements of engineering practice is one which is dependent for its operation solely upon the occurrence of reverse current flow. It is desirable also that loss of voltage shall not cause the opening of the "Reverse Current" circuit breaker, and it should be so constructed that it can be closed upon open circuit. In order to meet the varying conditions which may arise in the use of the circuit breaker, the volume of reverse current necessary for its actuation should be subject to convenient adjustment. The operation of the circuit breaker should be independent of voltage variations throughout the normal working range, and should be positive at all voltages to which it is liable. The force tending to cause the opening of the circuit breaker upon reversal should increase with the volume of the reverse current. In these last respects, particularly, many of the reverse current devices on the market are conspicuously defective. Considering, as an instance,

those which depend for their opening force upon a tripping coil which, when brought into circuit by means of a polarized relay actuated by a reversal of the current, is energized by the voltage of the system, it will be seen that where the reversal reaches the magnitude of a short-circuit, the voltage of the system may be reduced to but a fraction of its normal value, and the tripping coil may, as a result, be insufficiently energized to effect the opening of the circuit breaker.

Where, in order to avoid this very evident cause of failure, the tripping coil is connected in an independent circuit, new complications are introduced without corresponding advantage.

Obviously the operation of any safety device should depend entirely upon the conditions prevailing in the circuit to be protected, and its effectiveness should not be determined or limited by the condition of some independent circuit or appliance, the failure or disconnection of which may render the safety device inoperative at the critical moment. The following is a description of the I-T-E "Reversite" circuit breaker, upon the perfecting of which we have been at work for a number of years. In its operation all of the foregoing requirements are fully met.

Referring to the accompanying illustration (Plate I), it will be seen that the reversal feature of this circuit breaker is secured by the co-operation of two electro-magnetic systems: one consisting of a pivoted core and pole pieces depending for excitation upon a coil connected in the main circuit; the second of two independent cores, parallel with the first and excited in sympathy with each other by two magnetizing coils which are subject to the full voltage of the circuit. The pole pieces of the series magnet normally stand just midway between the polar extensions of the cores of the shunt-wound system. In this position they are supported from below by suitable stops. They are free, however, to move upward into engagement with the upper core, and in so doing cause the release of the latch restraining the switch. The windings and connections of the exciting coils of these two systems are so related that

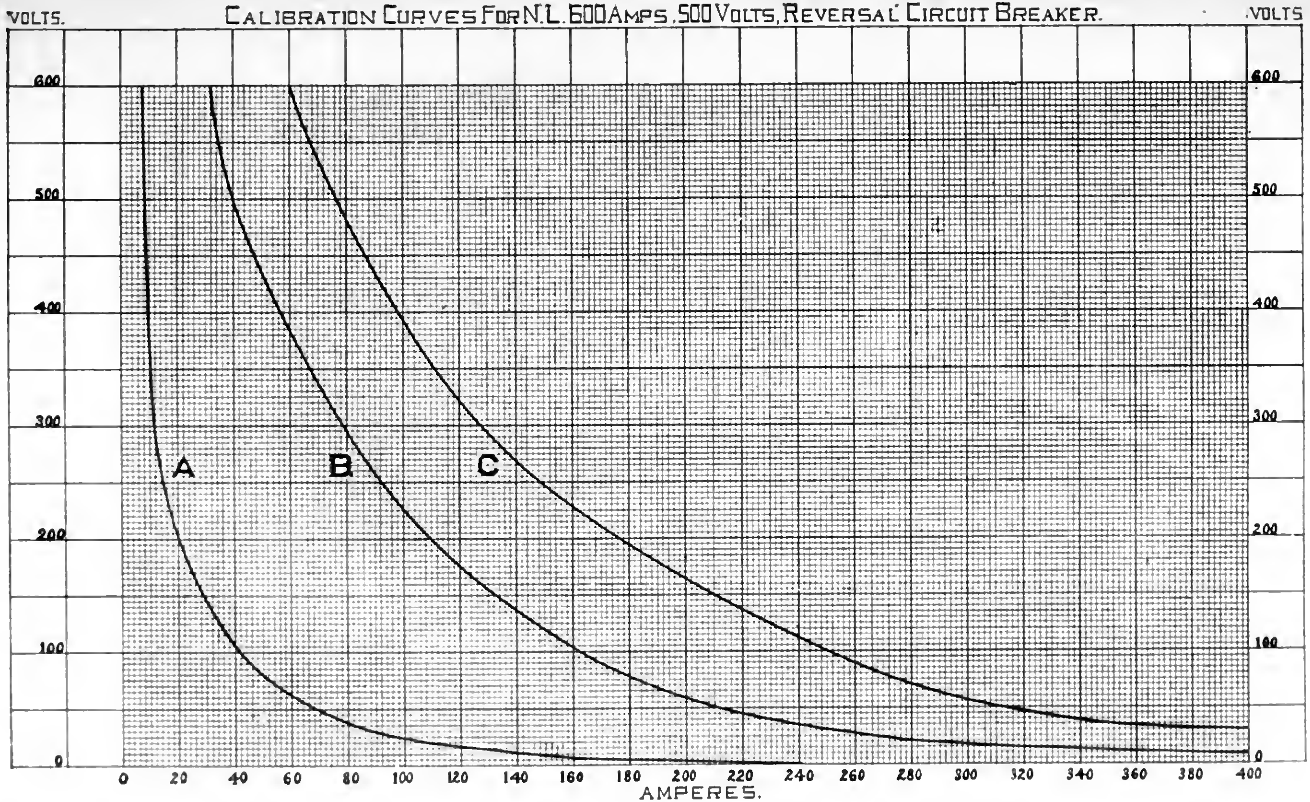
during the flow of current in the direct sense the movable pole pieces are held in their medial position by the attraction of the lower core acting in addition to the effect of gravity, while upon a reverse current flow the pole pieces are drawn upward in opposition to gravitation into engagement with the upper core, these opposite reactions being due to the fact that the magnetism induced by the

PLATE I.—I-T-E "Reversite" circuit breaker, with overload actuation.

shunt coils is not subject to change in direction upon a reversal in the main circuit. Upon direct current flow, therefore, the series magnetism compounds with that of the lower shunt magnet, while upon reverse flow it compounds with that of the upper one. It will thus be seen that the operation of the

circuit breaker is dependent upon the co-operation of voltage and current. Although on account of the location of the movable pole pieces midway between the shunt-excited cores, the voltage alone will not cause the operation of the circuit breaker; nevertheless, at and considerably below normal voltage, the shunt excitation provides quite sufficient power for this purpose, when made effective by placing the movable pole pieces above their neutral position; but upon reversal the magnetism due to the flow of reverse current supplements that of the shunt-excited core toward which the movable pole pieces are attracted. The effect of this in insuring positiveness in the operation of the circuit breaker may be best understood by an inspection of the accompanying diagram (Plate II), illustrating the performance of a 600-ampere " Reversite " circuit breaker, designed for the protection of a 500-volt generator operating in multiple with others similarly protected.

The ordinates of these curves correspond with the various voltages upon which the circuit breaker was tested, the abscissæ with the corresponding reverse currents required for the operation of the circuit breaker and consequent opening of the circuit. The three curves coincide respectively with 8, 20, and 75 amperes adjustment, which are correct at 500 volts pressure. It will be noticed that for variations of 100 volts either way from normal the performance of the instrument corresponds closely with the calibrations, that as the voltage of the circuit falls the value of reverse current necessary for the operation of the instrument continues to increase; but within the limits of the test, which was carried down to 30 volts, the operation of the instrument was uniformly reliable and positive. When at any voltage the reverse current had reached such a value as to cause the initial motion of the movable magnetic system away from its neutral position, there was ample energy supplied for the tripping of the circuit breaker. An inspection of the curves shows that they are of the nature of rectilinear hyperbolas, the asymtotes corresponding respectively with a vertical line drawn through the zero value of the current, and with a horizontal line somewhat below the zero volt-



VOLTS.
CALIBRATION CURVES FOR N.L. 600 AMPS. 500 VOLTS, REVERSAL CIRCUIT BREAKER.
VOLTS
600
500
400
300
200
100
0
A
B
C
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
AMPERES.

PLATE II.

age, the form of the curves bring represented approximately by the equations $X(Y + K) = C$, in which X corresponds with actuating current, Y with voltage, and C a constant, while K depends on residual magnetism, which, as will be seen, has the effect of reducing the values of the operating current, at the lower voltages, below that which would be required were the magnetism exactly proportional to the current. That the residual magnetism corresponds in direction with that induced by the reverse current is due to the fact that the only closing of air gaps in the magnetic system is such as results from reverse current flow.

Whatever may be the interest in the properties of these curves, they clearly indicate the reliability of the I-T-E "Reversite" circuit breakers under all conditions which may arise in practical service.

The I-T-E "Reversite" circuit breakers described above are provided with a convenient adjustment determining the value of the current upon which they will operate. This adjustment is obtained by the movement of a counter-balance along a calibration plate, the scale being long and easily read. The normal range of adjustment is from 5 per cent. of the normal capacity of the circuit breaker to 25 per cent., but any other specifications can be met.

The principles of the I-T-E "Reversite" circuit breakers are such as lend themselves with suitable modifications to designs for alternating current service.

Where alternating current work is considered instead of direct, the necessarily high inductance of the shunt coils of the reversal feature introduces an entirely new and highly important factor. By means, however, of designs which have been the result of much careful research and experiment, this and other difficulties have been overcome, and the engineer now has at his disposal for alternating current service, as well as for direct, a reverse current circuit breaker which will fully meet the most exacting requirements. The design of the alternating reverse current feature is such that on a circuit of ordinary power factor, the magnetism due to the shunt coils during normal conditions is approximately in phase with that due to the line

current. The reactions between the two magnetic systems of the reversal feature are determined not only by the magnitude of the current, but by its phase relation to the E.M.F. The reverse current may be considered as made up of two components; one in phase with the E.M.F., representing reverse energy flow, and a second lagging 90° behind the E.M.F., representing a wattless flow. The construction of the I-T-E reversal feature is such that it responds only to the first-named component, the wattless currents having no appreciable effect on its operation. For this reason the calibrations are marked in units of power, not in units of current, and indicate, therefore, the energy reversal which will cause the opening of the circuit breaker. It will be seen that these indications can be checked by ammeter readings only when the phase of the current and the voltage of the system are also taken into consideration.

THE APPLICATION OF REVERSE CURRENT CIRCUIT BREAKERS TO THE PROTECTION OF GENERATORS.

So long as generators are operated singly, their protection is fully insured by the use of simple overload circuit breakers. When, however, generators are operated in multiple, new conditions are introduced which require protective appliances having features not found in the simple "Overload" circuit breakers. Where generators are run in this manner, in case of accident to one of them or to its prime mover, not only will this unit cease to deliver its quota of current to the external circuit, but the other units in parallel with the damaged one will begin to force current into it. The normal generators will, therefore, supply not only an undue share of the effective load, but also additional current delivered to the crippled unit, resulting in unnecessary overloading of the normal generators and a possibility of injury to the crippled one. The use of simple "Overload" circuit breakers would, in such a contingency, result in cutting out the disaffected generators as well as the crippled one, with the result that, momentarily at least, the service would be interfered with. It is evident that the protective device for the generators should be of

such a character that the crippled unit shall be automatically disconnected before it shall have taxed the others. Thus the load will at once devolve upon the normal units without even a momentary interruption of the current supply. The only protective device which adequately meets these requirements is the I-T-E "Reversite" circuit breaker. Where each generator of the system is thus protected, crippled units will be immediately disconnected.

The protection afforded by "Reversite" circuit breakers is of especial value in power plants, the demands upon which are such that reserve units must frequently be thrown into service. Such a requirement is often of the nature of an emergency, and it is of the utmost importance, therefore, that the necessary connections shall be made promptly. If, however, the engineer connects the reserve unit to the bus bars an instant too soon, in the absence of proper protective devices, the current reverses into it and it thus adds to the load upon the other generators. Where each generator is protected with an I-T-E "Reversite" circuit breaker, no unit can be effectively thrown into parallel with the others until it is up to the voltage. The use of this type of circuit breaker gives the engineer confidence, saves delay and affords the generator complete protection.

"Reversite" circuit breakers also have an incidental value, in that they serve to automatically disconnect each generator, as its prime mover is slowed down when the generator is being taken out of service, as the instant the slowing down results in a drop in voltage of the generator, a reversal takes place which opens the circuit breaker.

The method of connecting "Reversite" circuit breakers for the protection of generators operating in multiple is shown in the accompanying cut, Plate III. The two poles of the circuit breaker are introduced in the usual manner into the circuits of the generator leads; the shunt coil is then connected so as to receive full line pressure. One terminal of the coil is to be attached to the small spring contact located back of the left-hand switch member of the circuit breaker; the other terminal must connect with the

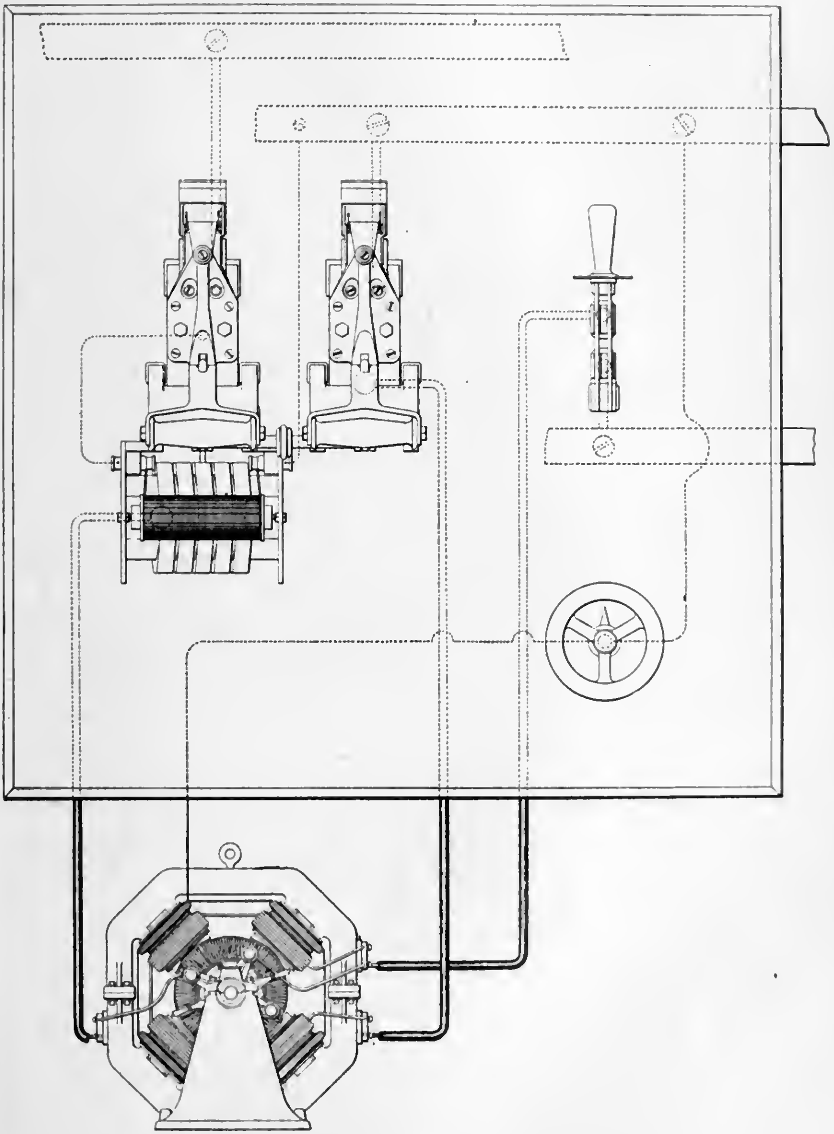


PLATE III.

bus bar of opposite polarity. The actual passage of current from the generator is perhaps the best method of ascertaining whether the shunt coil has been connected so as to make the circuit breaker operative upon reversal. If, upon trial, the reversal feature responds to current flowing in the direct sense, the connections of the shunt coil should be reversed.

Alternating current generators operating in parallel are subject no less than are direct current generators to reversals of current. Some idea of the correctness of this statement may be gathered by an inspection of the ammeters on the switchboard in any alternating current plan. Obviously, the total current delivered to the bus bars by a number of genators in multiple, should closely approximate the total current delivered from the bus bars to the external circuit. The excess of the former as compared with the latter is a measure of the current passing between generators and thus diverted from the external circuit.

To many engineers in charge of alternating current plants, the operations of the alternation current are filled with mystery, and they are, therefore, inclined to accept the guarantee of manfacturers of the generating apparatus of which they are in charge, rather than to reckon with the obvious facts of the case. The protection of alternating current generators with "Reversite" circuit breakers places a check upon the operation of these generators and will enable the engineer, by suitable adjustments of generators and prime movers, to get the best possible performance from them, or to locate such apparatus as is hopelessly at fault in this respect.

THE APPLICATION OF REVERSE CURRENT CIRCUIT BREAKERS TO THE PROTECTION OF ROTARY CONVERTERS.

The operation of rotary converters in parallel is analogous to that of other generating apparatus, and corresponding conditions may readily arise, causing one or more rotaries so connected to operate in the reverse sense; that is, taking current from the direct current side and delivering power to the alternating current mains. Where the rotaries are

protected by "Reversite" circuit breakers, such tendencies are arrested in their incipient stages. The "reversal" feature of the circuit breaker may most conveniently be installed in the direct current side, the switches of the breaker controlling either the direct or alternating current side, or both, as the requirements of the installation may demand.

Where rotaries are started from the direct current system, the reverse current breaker, in order to conveniently permit the passage of the starting current, may be made inoperative during the starting period by opening the circuit of the shunt coils of the "reversal" feature. This is most readily accomplished by means of a small switch in the shunt coil circuit interlocked with the line switch of the rotary on the alternating current side, so that the shunt coils will receive current only when the rotary is connected with the alternating current mains.

THE APPLICATION OF REVERSE CURRENT CIRCUIT BREAKERS TO THE PROTECTION OF TRANSMISSION LINE IN MULTIPLE.

Where power is delivered to a single receiving point by more than one system of feeders, it will be seen that in the absence of suitable protective devices properly disposed, a short-circuit upon one set of feeders will be fed not only through the portion of the feeder located between the short-circuit and the source of supply, but also by means of the portion of the damaged feeder beyond the short circuit, with current flowing in the reverse sense from the receiving station. "Overload" circuit breakers at both generating and receiving ends of the cables form a means of isolating the damaged lines. Their use alone, however, is liable to cause momentary interruption of service in the uninjured cables, which will be repeated until the damaged line is finally located and put out of service. Circuit breakers having reverse current operation located at the receiving end of the transmission lines will automatically sever the damaged cables at this end and prevent the receiving station from feeding back into the short circuit; this being attained without even momentary interruption of the service. These

considerations have equal importance in both direct current and alternating current practice, with perhaps a wider scope of application in the latter field. In combination with "overload" circuit breakers at the generating end of the feeders, "Reversite" circuit breakers at the receiving end should give adequate protection under all conditions of service which are likely to arise.

THE APPLICATION OF REVERSE CURRENT CIRCUIT BREAKERS TO THE PROTECTION OF STORAGE BATTERIES AND SYSTEMS OF WHICH STORAGE BATTERIES FORM A PART.

The wide application of storage batteries in connection with electrical installations of various types renders desirable a knowledge of the forms of protective apparatus best suited to the requirements of this class of service. The manner in which the storage battery is handled plays a very important part, both in determining the length of its life and its efficiency. Where batteries are charged at too high a rate, the plates are subject to sulphating and other forms of injury, from which the battery is slow to recover. Discharge of the battery under abnormal conditions is also likely to cause serious damage. Where storage batteries are constantly under the eye of skilled attendants, guided by suitable indicating instruments, these dangers are perhaps somewhat reduced. They may in all cases be minimized and in most cases entirely eliminated by the installation of suitable protective devices.

Considering first the protection of automobile storage batteries, these are quite frequently charged from a generating plant devoted exclusively to this purpose. Among the contingencies likely to arise, are: connecting the battery into circuit incorrectly, so that its electro-motive force shall be cumulative with that of the generators, thus subjecting the batteries to an abnormally high discharge rate; or, where the battery is properly connected, it may be subjected to a charging current in excess of its safe limit. Disastrous results from such causes may be entirely prevented by the use of "overload" circuit breakers.

During the period of charging, should the charging

generator lose its field, or for any other reason drop its voltage, the storage battery will tend to reverse into it and operate it as a motor, and this without such indication of abnormal conditions as would attract the eye of the attendant. The battery would thus, to all appearances, be charging, while in point of fact it would be undergoing discharge, resulting not only in undue waste of energy, but wear and tear on the battery and loss of time as well. A somewhat similar condition is likely to arise where the battery is charged from a generator engaged in supplying current to an external circuit. Under these conditions, the causes of reversal of the battery into the generator would be the same as those already cited, and in addition thereto, should the generator for any reason be cut out of service, the battery would take up the load on the external circuit, and thus again the attendant might readily be misled as to the real condition of affairs. Particularly would this be the case if the generator were remote from that point in the circuit to which the storage battery was connected. A "Reversite" circuit breaker in the circuit of the storage battery would serve automatically to disconnect the battery coincident with the first flow of current from it into the external circuit.

Sometimes in automobile charging stations, a number of batteries may be left in connection with the same charging mains at a time when the generators are disconnected. Where this occurs, the stronger or more highly charged batteries will discharge themselves into those more nearly exhausted, and should any one of the batteries be short-circuited, this would result in injury to all of the others. This contingency also may be guarded against by the installation of a "Reversite" circuit breaker in each battery-charging circuit as shown in Plate IV, which represents a panel such as may be employed in charging a battery from a constant potential circuit, the current being regulated by the line rheostat shown in the lower section of the panel.

Very frequently batteries, particularly those of automobiles, are charged from a motor generator especially installed for that purpose. In such instances, most fre-

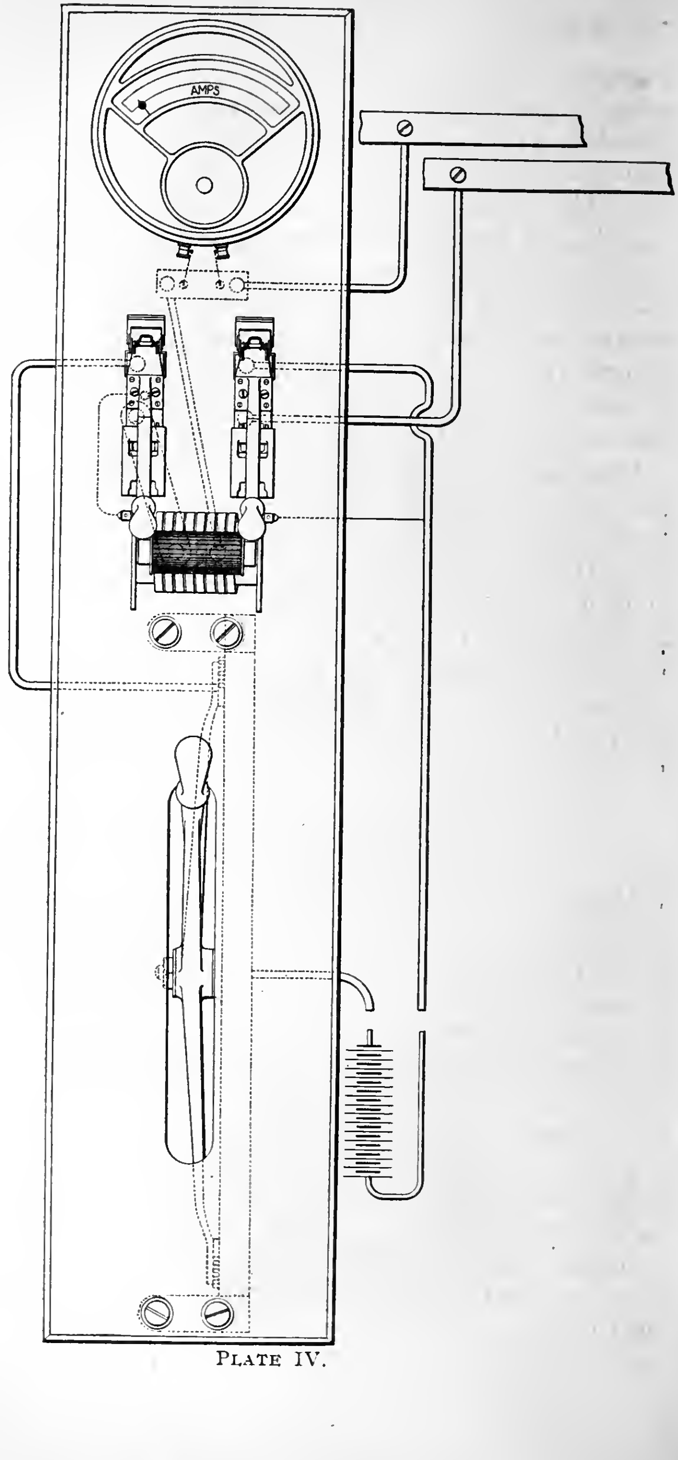


PLATE IV.

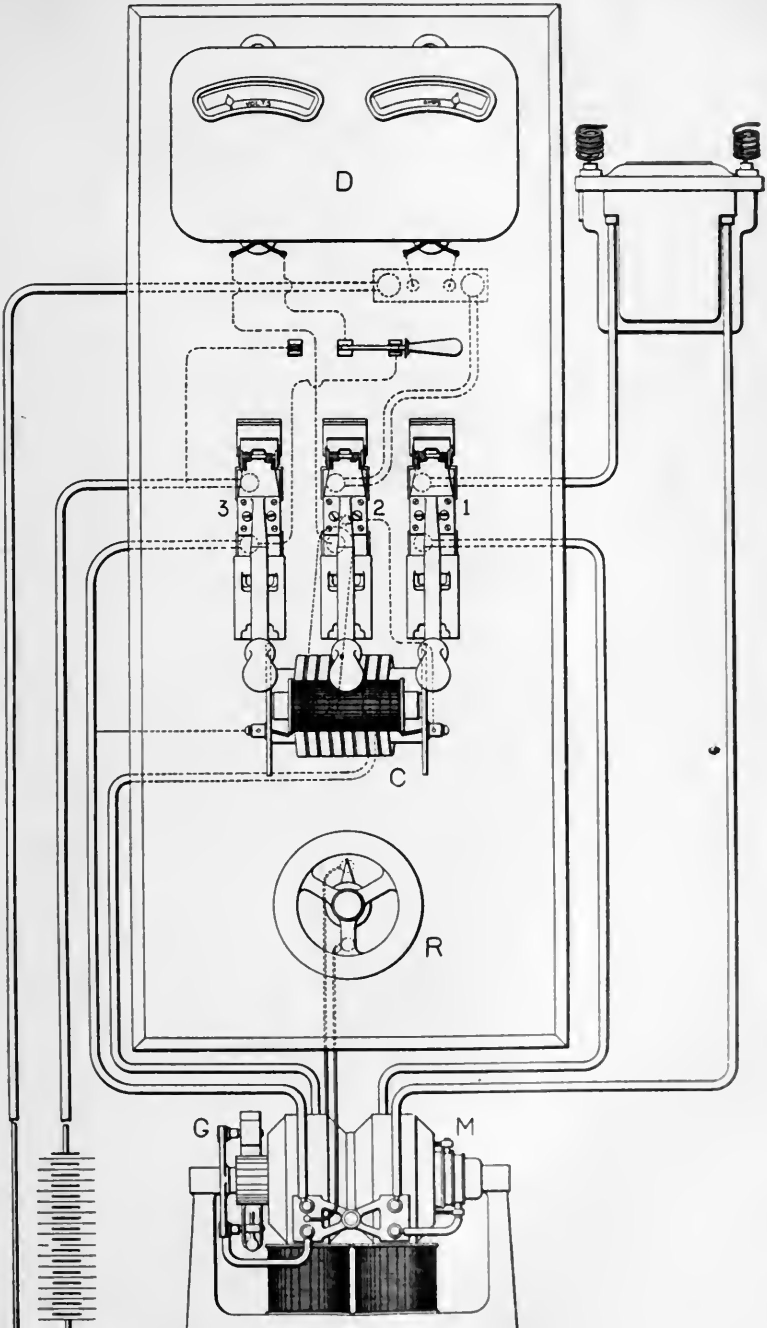


Plate V.

quently the circuit from which the motor side of the charging set is driven is in connection also with other apparatus. If for any reason there should be an interruption of the motor circuit, as might be occasioned, for instance, by the opening of the circuit at the power-station, the storage battery, if not promptly cut out, would run the motor generator in the reverse sense, the motor end acting as a generator and supplying current to the other apparatus on the feeder. The installation of a "Reversite" circuit breaker in the charging circuit of the storage battery provides the only effective means of protection against this contingency.

Conditions identical with these are frequently met with in telephone work. The suitability of the "Reversite" circuit breaker to this class of service is perhaps best instanced by the large and constantly growing use of this piece of apparatus by the leading telephone companies of the country.

A convenient and effective method of installing the "Reversite" circuit breaker for the protection of systems referred to is suggested in the accompanying diagram—Plate V. *M* is the motor, and *G* the generator, the voltage of the latter being controlled by the field rheostat *R*. At *D* (frequently combined in a single case) are the voltmeter and ammeter, the latter in the battery circuit, while the former, by means of a two-way switch, may be used to measure either battery or generator voltage.

C is a three-pole combine overload and "Reversite" circuit breaker with independently operating arms. The pole "2" of the circuit breaker, which includes the overload and reverse current operating coils, is located in one of the mains leading to the storage battery, whose connection with the generator is completed through pole "3" of the circuit breaker, pole "1" of which is included in the motor circuit.

In starting up, the motor circuit is first closed through pole "1" of the circuit breaker; by means of the field rheostat *R* the voltage of the generator is equalized with that of the battery, which is then connected with the generator by closing the two remaining poles of the circuit breaker, after which the voltage of the generator is increased until the

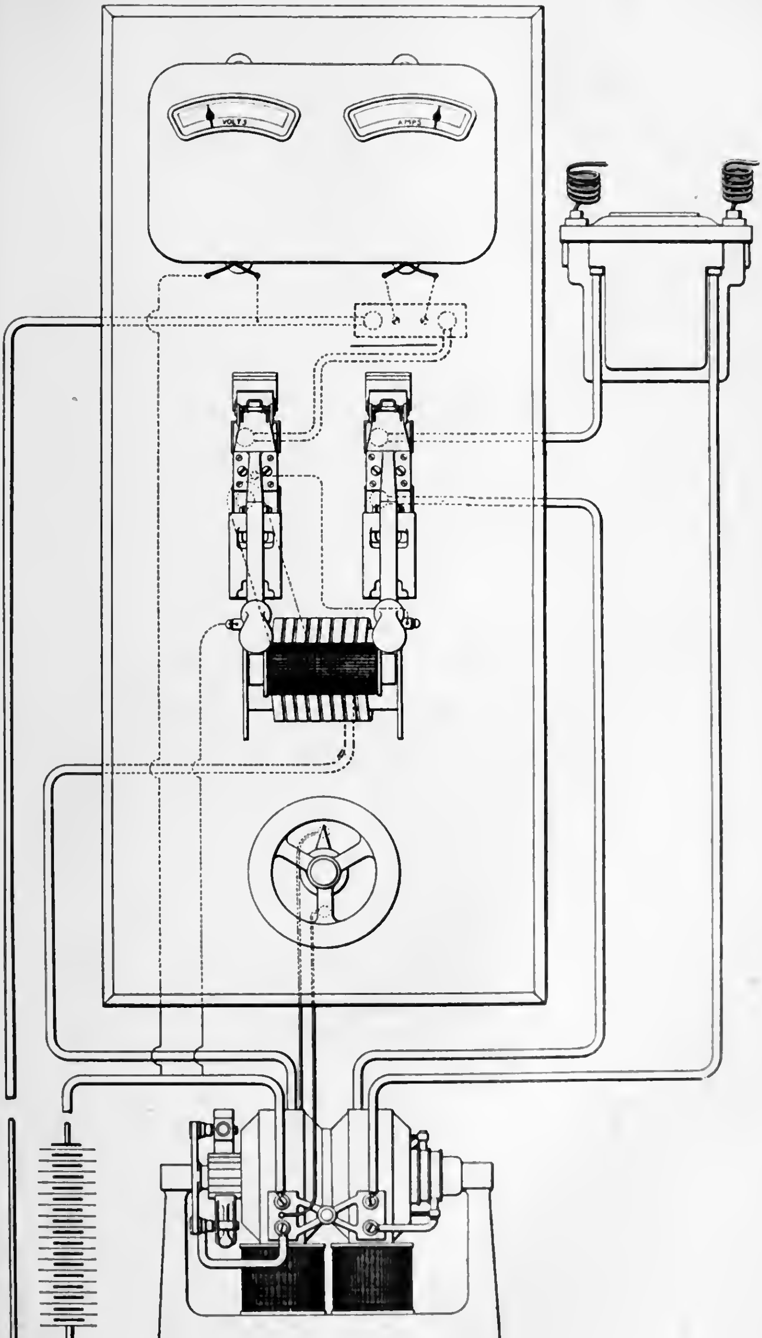


PLATE VI.

proper charging current flows. While this plan is simple in its arrangement, it is very effective in operation, and provides for the immediate opening of both motor and battery circuit in the event either of the battery being too rapidly charged, or of its reversing into the generator. It will be seen that the construction of the circuit breaker embodied in this equipment is such that the battery cannot be effectively brought into circuit, either upon reverse current or upon overload conditions. Two independent poles being included in the circuit of the battery, the instant opening of the circuit is insured should an attempt be made to connect the battery under conditions resulting either in an overload or a reverse flow of current. Plate VI shows a similar panel employing a double-pole circuit breaker, of which one pole only is connected in the battery circuit and one in the motor circuit.

Very frequently storage batteries are installed in multiple with motor-driven generating units, acting under normal conditions as an auxiliary thereto, relieving the generator of the peaks of the load, and carrying the load entirely during interruptions of the main source of power. Such installations as these are constantly increasing in use in connection with electrically operated signals, where interruption of the current supply must at all hazards be avoided. In this case it will be seen that the current in the battery circuit may, under normal conditions, flow either in the charge or discharge direction. A reverse current circuit breaker installed between the battery and the external circuit on the one hand, and the generating side of the motor generator on the other hand, will serve, however, to keep the current in this part of the circuit flowing in one direction only, a reversal of the current from the battery into the generator at once throwing the generator out of circuit, leaving the storage battery to carry the load.

A plan embodying these principles is shown in the accompanying Plate VII. Its distinctive feature is that it provides two sets of batteries as a safeguard against shutdown. The arrangement is such that both batteries may be charged or discharged at the same time, and either or both

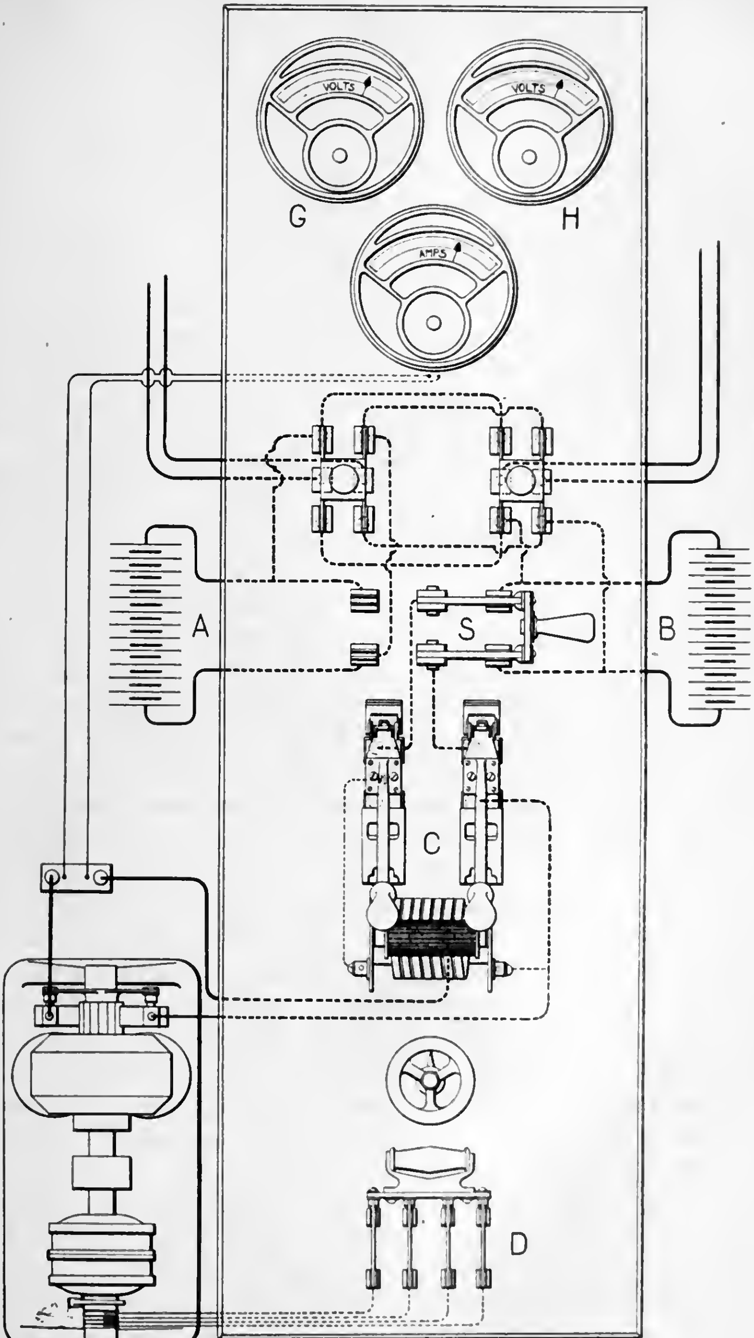


PLATE VII.

may, if required, carry a whole or a part of the load with or without the assistance of the generator.

These batteries are indicated at *A* and *B*. The double-pole, double-throw switch *S* serves to connect either one with the charging generator through the Dublarm overload and "Reversite" circuit breaker *C*. The power is supplied by a two-phase alternating current circuit controlled by switch *D*. The feeders, two in number, are connected with the hinges of two double-pole, double-throw switches, the upper and lower terminals of which connect respectively to batteries *A* and *B*. The voltages of generator and batteries are indicated by voltmeters *G* and *H*, the latter of which is controlled by a two-point switch, so that it may be connected with either battery. A field rheostat affords means of varying the voltage of the generator, which is shunt-wound. By using a circuit breaker with sufficient number of poles, the motor side also of the charging set may be disconnected simultaneously with the opening of the generating side. This, however, is in many cases a refinement of economy rather than necessary means of protection.

In lighting and power-work a storage battery is sometimes installed in multiple with the generator, charging from it at low loads, assisting it by carrying a portion of the heavier loads. This class of service demands treatment somewhat different from the foregoing, and its requirements may usually best be met by installing a "Reversite" circuit breaker, the series actuating coil connected in the main circuit of the generator, between it and the storage battery, the switch member being in the battery circuit. The battery will thus be free to charge from the generator or discharge into the external circuit, but any tendency to reverse into the generator itself will cause the immediate severance of the storage battery circuit, leaving the load upon the generator.

For all of the classes of storage battery work referred to in the foregoing paragraphs, it is believed that the I-T-E "Reversite" circuit breaker (with or without overload actuation, as dictated by the conditions to be met) affords the best possible protection.

For the charging of storage batteries at constant voltage, the "I-T-E Underload" often affords entirely satisfactory protection. It is to be remembered, however, that this device will not remain closed unless there is flowing in the circuit a sufficient current to restrain the underload armature. Where the voltage of the circuit is liable to fluctuations, this would result in frequent and unnecessary opening of the "Underload" circuit breaker, a condition that is entirely absent with the use of the "Reversite" circuit breaker, which will not only remain closed when no current is flowing in the line, but, as before explained, requires an actual reversal in the direction of the flow of current to cause its operation.

THE APPLICATION OF CIRCUIT BREAKERS TO THE PROTECTION OF STORAGE BATTERY BOOSTERS.

The discussion of the protection of storage batteries leads naturally to the consideration of means for protecting the booster sets commonly used in connection with battery installations. In the majority of cases, where boosters are employed in such systems, they are used reversibly, that is, they are employed to regulate both the charge and the discharge of the storage battery. Obviously, therefore, reverse current circuit breakers, as usually understood, are not suitable for the protection of this portion of the circuit. The I-T-E combined overload and "Reversite" circuit breaker may, however, be admirably adapted to these conditions. When intended for such service, the reverse current adjustment is made to correspond with the maximum safe charging rate of the battery, the overload adjustment conforming with the maximum safe discharging rate. Adequate protection is thus afforded to the battery with either direction of the current flow.

Boosters of the compound or series type, if left connected with the system when the circuit of the driving motor is interrupted, will act as series motors rotating in the reverse direction, and, if not promptly disconnected, will attain a destructive speed. Similar conditions occur should the booster circuit be closed before the motor has been started,

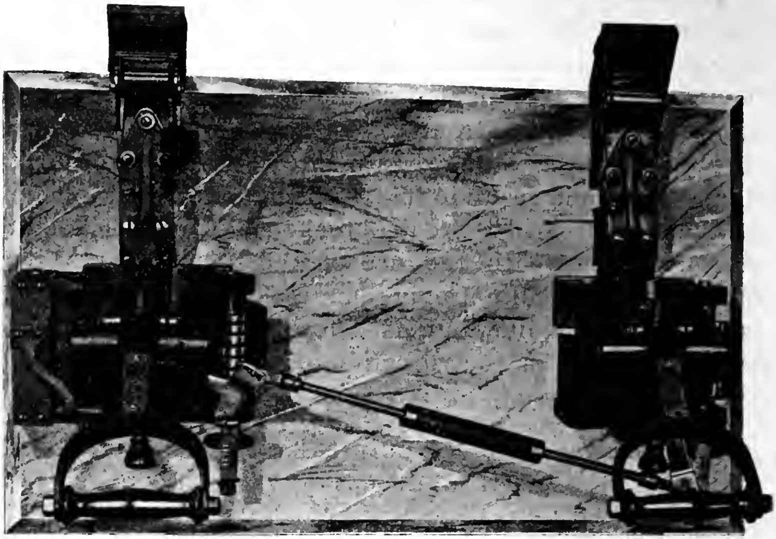


PLATE VIII.

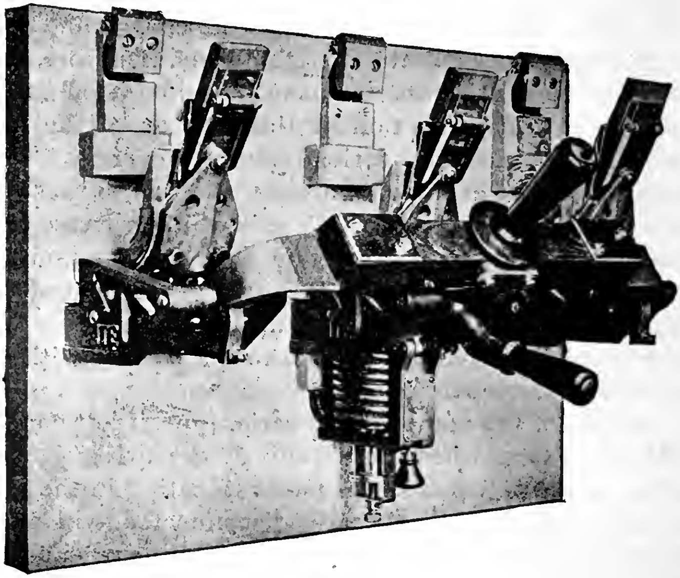


PLATE IX.

or should the motor for any reason lose its field. Proper protection under these conditions is secured only by having an overload and no-voltage circuit breaker in the motor circuit inter-connected with the circuit breaker in the battery circuit in such a manner that the motor circuit breaker must be closed before the booster circuit breaker can be made to latch, while the opening of the first-named instrument instantly causes the opening of the second.

The inter-connection of the circuit breakers may be either electrical or mechanical. Where the electrical method is employed, the booster breaker is provided with an auxiliary tripping coil brought into circuit by means of a contact device operated by the opening of the motor circuit breaker. In the mechanical arrangement, a lever suitably connecting motor and booster breakers is actuated upon the opening of the former, to release the latch of the latter. This method of inter-connection is illustrated in the accompanying cut, Plate VIII.

THE APPLICATION OF CIRCUIT BREAKERS TO THE PROTECTION OF BOOSTERS SUPPLYING FEEDERS.

Boosters employed to compensate voltage losses in feeders, incident upon transmission over considerable distances, are either series or compound wound; if, therefore, when for any reason the driving motor is not receiving current, the booster should be left in connection with the system, it will run reversely as a motor, and in view of its series field winding will attain destructive speed. This condition may be adequately dealt with by the employment of inter-connected circuit breakers as described in the foregoing section, the motor circuit breaker being of the overload and "no-voltage" type, while the circuit breaker in the booster circuit will, as a rule, need no other actuation than that transmitted from the motor breaker by the inter-connecting device.

Plate IX shows a type of circuit breaker which has been very successfully employed in connection with booster sets having a generator on each side of the line. The outer switches serve to connect the two boosters to the positive

and negative sides of the line respectively; the center circuit breaker operating upon either overload or "no-voltage" serves also to cause the opening of the booster switches.

THE PENETRATING POWER OF "N_1-RAYS."

Professor Blondlot recently drew attention to a novel kind of N-rays, diminishing, instead of augmenting, the phosphorescence of calcium sulphide. These rays, called by him "N_1-rays," are given off from a Nernst lamp simultaneously with the N-rays, and are also produced by stretching out a copper, silver or platinum wire.

In a memoir recently presented to the French Academy of Sciences, Mr. Julien Meyer describes some experiments with these N_1-rays, produced by an extended glass or copper wire or else by a closed glass tube in the interior of which the pressure is diminished. The glass of the tube, on account of the strain resulting from the difference in pressure, was in fact found to be a powerful source of N_1-rays. The brilliancy of a screen covered with sulphide spots and introduced into a glass bulb resting on the plate of an air pump would diminish when the machine was started, but would recover its initial value as the air was allowed to re-enter. If the sulphide screen be placed outside of the bulb, the phosphorescence would likewise diminish from the very first stroke of the piston. An incandescent lamp bulb, not traversed by any current, a hydrogen Geissler tube, a Crookes' tube, were all found to be sources of N_1-rays without being actuated by a Ruhmkorff coil.

While the N_1-rays from a Nernst lamp are arrested by an oxidized lead plate or by a sheet of moistened paper, those issuing from the sources named are gifted with a high penetrating power; in fact, the action of incandescent lamp bulbs on the screen is not appreciably diminished if between the bulb and the screen there be inserted a board 10 centimeters in thickness or a sheet of oxidized lead 1 millimeter in thickness and folded around itself so as to be traversed eight times, or else a glass vessel filled with pure water. Pasteboard, paraffin, aluminum, zinc, iron, copper, silver, gold, mercury and the hand are also transparent to these radiations. The only opaque bodies found were platinum of a thickness of 1 millimeter and opalescent glass 3 millimeters in thickness.

While examining the refraction of the rays by means of an aluminum lens, the author stated that this metal would store the rays in great amounts, giving them off again for more than twenty-four hours after it had been withdrawn from the source. A similar power, though of smaller intensity, was found in the case of ordinary glass; while lead, copper and pure water did not show it.

Salt water and a solution of sodium hyposulphite in water, on being submitted to the action of a source of N_1-rays, would become active themselves, acting as sources for a very long time.

When the hand is held for some time at a small distance from a source of N_1-rays or touching the latter, the hand would diminish itself the phosphorescence of the screen, this property being kept for some minutes.

N_1-rays as given off from the above sources are refracted by glass, copper and aluminum prisms and diffracted by a grating.—*Scientific American.*

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, June 15, 1904.

The Naval Strength of the United States.

By Geo. W. Melville,
Rear Admiral U. S. N.

Neither the actual nor the relative naval strength of the United States, as compared with that possessed by Continental Powers, can be measured alone by the number and character of the warships of the respective countries. While graphic charts may show the relative amount of displacement, as well as the amount and character of armor and armament possessed by the several powers, there are other factors that must be taken into consideration in determining relative strength, for the ability to keep the ships in a fighting state of efficiency is only one remove in importance from constructing them. It is because our actual naval strength is greater than that represented by the size of our fleet that our influence as a world power extends beyond our own shores.

War is now a business rather than an art or science, and therefore it is bullion and brains, as well as bullets and brawn, that must be considered by nations undertaking or contemplating hostilities.

War can no longer be indulged in by weaker countries without risking their existence as nations. An occasional revolution or insurrection is the nearest approach to war that the weaker countries can experience, for the tendency of the age, if not manifest destiny, is to make it impossible for the smaller powers to bring on a general conflict. It is like the pauper aping the millionaire for weaker countries to indulge in war. It is certain that when weaker nations imperil the balance of power, by provoking a conflict, that such action inevitably means the absorption of a weak by a stronger power.

The doom of that nation is sealed which does not possess

some foreign markets, and as this trade can only be retained when once secured by the possession of a merchant marine and a powerful navy, the question of relative naval strength is one that concerns the commercial, maritime and military interests of the country.

EFFICIENCY OF OUR WARSHIPS AND NAVAL PERSONNEL.

Our navy, though small, possesses an efficient personnel, a well-built material, and an administrative organization that is well adapted to existing needs. Our actual naval strength, however, represents more than our number of battleships built and building.

The size of the battleships, the resisting power of the armor and the character of the armament must always be regarded as important elements in determining the capabilities and possibilities of any naval fleet. The value and importance of a trained personnel should likewise be recognized in its fulness. The administrative feature is also an important element, for however efficient a navy may be for peace purposes, the safety of a nation would be impaired if the administrative organization was not of such character that would make provision for the expansion of the navy to the necessity and demands of war.

ADMINISTRATIVE ORGANIZATION AN IMPORTANT FACTOR OF NAVAL STRENGTH.

The present organization of the Navy Department is a remarkably strong and able one. The victories of both the Civil and Spanish-American wars were the outcome of the working of that splendid and developed administrative system. Its efficiency has been tested, and in reviewing the military events of the war with Spain, foreign critics have emphasized their admiration of the splendid administrative organization that we possess. The Navy and the Nation should be slow to give up an organization that is so simple that its detail work can be comprehended within a few weeks by every executive administrator upon assuming office. The country at large is also familiar with its method of doing business. The operations of the navy have been so developed that there is an admirable system of checks

and counter-checks whereby fraud and corruption are practically made impossible. The system is admirably suited to progression and advance, and the deep affection which the country possesses for the naval service is due in considerable part to the manner in which the department has been administered. It is only necessary to recall that those who have served longest as executive heads of the Navy Department have had the least desire to seek a change in its administrative organization. There has not been a single type of ship designed at the Technical Bureaus that has not rendered efficient service. The abortions in the shape of warships have been the product of those who have not had technical experience and training, and it has been against the vigorous protest of the Construction Board of the Navy that such anomalies have been constructed. The Navy Department has ever been receptive for advice and information from the military officers, and any attempt to subordinate the technical and civil features of administrative organization to that of the military will not add to our military strength.

It is, however, neither the size of our fleets, the character of our crews nor the splendid administration of affairs that constitutes these primary features of the naval strength of the United States which are most feared and respected abroad. It is the reserve of wealth, resources and manufactures, as well as the great body of men capable of being trained to naval duties, that constitutes our actual power. It is the power to remain on the firing line, rather than our ability to get there, that is best recognized by our possible foes.

The events in the Far East afford a striking illustration of the fact that it will be the reserve battalions of the contesting foes that will decide the contest. It is the lack of munitions and financial resources that has prevented war.

OUR COLLATERAL FEATURES OF NAVAL STRENGTH MOST FEARED BY EUROPE.

In determining the relative strength of naval powers, there are, therefore, collateral issues involved other than

those of displacement, gun fire, armor protection, organization and personnel.

When the United States plunged into war with Spain, the strength of the warships of the two powers was about the same, so far as graphic charts and carefully-prepared tables could show. When there was a meeting of the fleets at Santiago, three months after the declaration of war, the squadron of Spain had become weakened, due to the failure of the vessels to secure ammunition, coal, men and even food supplies. On the other hand the ships of the American fleet were probably in better condition than they were at the beginning of the year, for a fleet of auxiliaries had brought to our vessels everything that was requisite for continuing efficiency. It was the collateral rather than the military features of naval strength that eventually brought about the relative difference in strength between Cervera's and Sampson's squadron.

The showing that can be made of ships and guns possessed by the several powers as a measurement of strength is more apparent than real. It is not necessary to doubt that the vessels of any nation are of the tonnage that they are claimed to be, nor need it be denied that practically all vessels lately constructed possess modern armor and armament. The stress of war conditions, however, will soon impair the condition of the ships unless there is an ample reserve of men, money and means of various kinds.

The four factors of displacement, armor, armament and skill of personnel are regarded by many naval experts as the substantial elements of naval strength. Each of these elements is of essential importance, but there are other things to be considered. Our continental rivals are ready to acknowledge that we are upon an equality with them as regards the penetrative quality of our armament and the character of our personnel. Yet by reason of our weakness in the number of trained men, and of our lack of an adequate supply of modern guns, it is maintained abroad that we are really behind Germany in these respects. If our strength is yet feared, as it surely is, it must, therefore, be due to our superiority in what some military men regard as unimportant collateral features.

The strength of the United States, as compared with other powers, has been so often and clearly shown from the standpoint of displacement, guns and enlisted personnel that it is only necessary to state that practically all strategists place England, France and Russia ahead of us. There is a difference of opinion as to whether Germany is in advance of the United States in actual fighting ships, that is, judging from the standpoint of the strategists and tacticians. It is certain that Germany expects to leave no doubt upon the question five years from now.

As one carefully reads the views, and hears of the undercurrent of the deepest thought of Continental naval experts, he is strikingly impressed with the fact that all are coming to the opinion that in determining this question of relative strength, some factors that have heretofore been omitted now are rising to primary importance, and thus the actual relative strength of the United States is regarded as much greater than that heretofore accorded by any of the experts.

The following are some of the factors that have been given too little consideration in the past, but which are now beginning to be realized in something like their fulness.

(1) The money required to carry on the operations of a modern war. It was asserted about twenty years ago by one of the best informed generals of the British War Office that the actual cost of every soldier in time of war would approximate a guinea a day. These figures were considered astounding, but the events of the Spanish-American and the South African wars showed that the cost was rather underestimated than overestimated. There is in the conduct of war a profligacy bordering on to wanton waste that seems unavoidable. As one reviews the events that occurred in Cuba, Porto Rico and the Philippines, it would appear as if the cost of the military campaign in those countries should not have been excessive, and yet the direct and indirect expenditures of our military successes in those countries has run into the hundreds of millions of dollars. The cost of the South African war was about five times that expected by even the most pessimistic of the British experts.

Although the British and American administrative officials had reason to anticipate war, and had made preparations for years for the impending conflict, the cost was excessive. From the time the call to arms is sounded, the cost of all supplies seems to increase rapidly, at least as far as military and naval expenditures are concerned. On the one hand, there is a fear of the invader, and as a result millions of dollars are wasted upon fortifying points that could by no possibility be attacked. Vessels are purchased and used for harbor defense whose only capacity to do harm would be in the direction of killing or maiming their own crew. The expenditures in connection with the transport service are simply typical of what goes on in every direction. The cost of war has thus reached a point when but few nations can indulge in the pastime. For a time war may stimulate the general business of a nation, but the reaction soon comes, and there, then, is a decade of taxation to pay for every year of strife.

From a financial standpoint the victor of a war derives as little benefit as the vanquished. Increased burdens and responsibilities are thrown upon the conqueror, and it is doubtful if an instance can ever be shown wherein the conquering nation was not compelled shortly after the termination of the war to increase the tax rate to meet new responsibilities and liabilities. The peace of the world at large is disturbed by every war, and the nation that takes unto itself territory from its defeated foe simply invites the jealousy, if not the envy, of other powers whose trade relations have been or are presumed to be affected.

It is the wealth of England and the United States and the ability of these countries to remain for a long period at war that is the great factor in preventing them from being attacked by others. With each succeeding year the material wealth of a country becomes a greater factor in determining its military power, and therefore there should be placed as of exceeding importance in determining actual naval strength this material wealth of a nation.

(2) The manufacturing, mining and agricultural resources of a nation must be regarded as military factors of great

importance. It is as essential to be able to keep battleships in efficient condition as it is to build them, and that nation which cannot manufacture its own armor, ammunition and ordnance, as well as repair its own ships, will not count much as a sea-power. The possession of battleships by the Chinese and by some of the South American republics is not seriously considered by thoughtful naval experts, for, by reason of their lack of manufacturing resources, the battleships of such countries must soon reach the scrap heap. That nation which does not possess coal fields, as well as beds of iron and copper ore, will never be able to carry on a protracted naval war. It was but a few years ago when a Continental military expert pointed out the important part played by glass in making preparation for war. In the transportation of various acids essential for the manufacture of war material, glass is absolutely necessary. In the various laboratories of all great industries, glass is used for countless purposes, and anything which would interfere with its manufacture would be a great hindrance to the output of much war material. The value of glass as a war material is thus brought to your attention in order to show how dependent a modern army and navy is upon the manufacture of some material that seems wholly used in the arts and sciences. It requires many links in the chain that keeps moving a great army and navy, and probably every general industry is an important contributor in some indirect way to national defense.

The experience of the United States in the winter of 1902–1903 as regards the available coal supply for domestic and manufacturing purposes gave the country a great surprise as to the comparatively small amount that was or even could be kept in store. Probably no article in common use—that is, of a bulky nature—has so short a reserve supply in stock. Only a small reserve is kept on hand either at the mouth of the mine or at the transportation terminals, since every storage means at least two handlings, and each handling represents a depreciation in both quality and quantity.

For a nation contemplating or engaging in war, coal,

or the want of it, is the life or death of a fleet. The want of it was Cervera's undoing. Had he had coal, he would never have been caught at Santiago "like a rat in a hole." The nation that cannot absolutely rely upon securing for its naval and mercantile fleet an adequate supply of good fuel will not figure for any lengthy period as a sea power.

Coal is a very bulky article, and under certain conditions will deteriorate rapidly. In its transportation, there are required extensive piers, expensive machinery and a vast amount of rolling stock. It is an extremely expensive undertaking to increase the facilities for transportation of fuel, and one of the greatest difficulties that will be experienced by Great Britain in the maintenance of her great fleet upon a war footing will be the securing of an adequate supply of coal. The average daily consumption of some of the great ocean liners is as follows:

"Oceanic"	480 tons.
"Lucania"	475 "
"Deutschland"	570 "
"Kaiser Wilhelm der Grosse"	500 "
"Kaiser Wilhelm II"	600 "

Each of the great ocean liners practically requires a coal train to keep it supplied with fuel, and when these vessels are employed upon service other than between two regular terminals, the question of coal supply will be of great importance. It requires about 50,000 tons of coal to supply the actual wants of the British ships taking part in the annual manœuvers. Hundreds of thousands of tons would be required annually by any naval power undertaking war, and the problem of storing and transporting this fuel rises to one of magnitude.

By reason of our possession of the Aleutian and Hawaiian Islands, and of the great distance between Japan and our Western coast, it would be almost impossible for any nation, except England, by reason of the problem of securing sufficient coal, to assemble a powerful fleet off any of our Pacific seaports. The capture or temporary destruction of the principal coal mines of British Columbia ought not to be a difficult matter; so that the principal seaports of

Washington, Oregon and California ought to be almost immune from any probability of blockade.

Now that an isthmain canal is an assured fact, our people should awake to the realization that we have taken a world's burden upon us, whether this burden be regarded from the military or financial standpoint. The tendency to build longer, broader and deeper draft vessels will compel the scope of the canal project to be enlarged, and as a result the cost of the waterway will not be far from $400,000,000. The natural features of the country environing the canal are of such a character that in order to prevent the impairment or destruction of this great waterway, every yard in length of the canal will have to be defended both by day and night, and it is a conservative estimate that does not provide for an expenditure of another additional $300,000,000 for the erection of forts, the building of battleships, and the maintenance of an army of defense or protection. Our new conditions are giving us new responsibilities, and the building of the Panama, as compared with that of the Suez Canal, may well be likened to the respective work of building a battleship and a gunboat.

The building of the interoceanic canal is going to have an important bearing upon our relative naval strength. It will bring upon us military responsibilities and cares, and greatly add to the cost of both military and naval establishments. It may compel us to fight great naval battles in the vicinity of the Bay of Panama, for it must ever be kept in mind that the best fighting nation of South America—Chili—has not altogether been satisfied with our past treatment of her.

With the coal fields of Pennsylvania within two days' reach of the New England seaports, with the Virginia and Tennessee fuel districts within two days of the Atlantic coast, and with the Alabama coal territory within two days of the Gulf ports, our capabilities for coaling warships is exceedingly satisfactory. For defense purposes the oil fields of California ought to be available in case of necessity as a means of maintaining the fuel supply of at least a fleet of coast defense ships.

While but few of the soldiers and sailors who volunteer for war ever reach the firing line, every one of them must be fed, and this simple statement ought to tell of the part that the agricultural resources of a nation figure in the business of war. For every man in England who fears an invasion from the Continent, there are a hundred who are apprehensive as to where the food supply of Great Britain is to come from when that empire is not at peace with a strong naval power. The granaries of Australia, India and America are so remote from the British Isles that it is going to require the service of a considerable portion of the British Navy to maintain the food supply of her people at home, and, therefore, every warship and armored cruiser possessed by that nation will by no means be available for the line of battle. The various powers of the Far East have but to look threateningly at each other before there comes an order to America for breadstuffs and meats. Even the question of securing sufficient hay and oats for feeding the comparatively few animals employed in warfare becomes one for thoughtful consideration.

THE MERCHANT MARINE OF GREAT BRITAIN TAXED TO SUPPLY TRANSPORTS FOR THE SOUTH AFRICAN WAR.

In conducting the South African war, it was necessary for England to transport the greatest army ever moved for any comparable distance. There was absolutely no molestation to the movement of troops, horses and munitions, and yet her merchant marine was taxed to the utmost to provide sufficient ships. There were, of course, available, as naval auxiliaries, many mail and freight steamers plying regularly between the British and other ports of the world. The impressment of such steamers, however, by the Admiralty and War Office would have resulted in the loss of British trade and commerce that might never have been restored. In case any small naval power had espoused the cause of the Boers, this movement of troops and munitions might seriously have been interfered with. It is certain that the insurance rates of merchant vessels would have been increased to a point where the shipping trade would have been other than a profitable business to British shipowners.

THE PROTECTION OF A MERCHANT MARINE IS A MILITARY PROBLEM UNTO ITSELF.

While a merchant marine must in the main be a valuable auxiliary to naval strength, the history of the world shows that the downfall of commercial and maritime nations has been repeatedly due to the possession of such a large undefended merchant marine that this commerce invited attack and became the prey of nations possessed of efficient fighting ships.

Closely associated with the defense of the merchant marine is that of distant colonies. The average colony is probably a tax rather than a support to the home nation, and by the time any colony becomes self-supporting, then comes the agitation for either great expenditures for internal improvements or for independence. It has been the defense of the merchant marine and colonial possessions that has caused the downfall of nations at various periods.

The experience of the Italian, Portuguese, Spanish and Dutch people may be repeated in the case of every nation that places too great a value upon the possession of a merchant marine. There is a Chinese proverb which says that the junk fleet of an opposing Viceroy constitutes a hostage that will always bring him to terms. It will not, therefore, be wise to place too much reliance upon the aid that can be rendered a navy by its mercantile fleet. While England has a great navy, the question may be seriously propounded whether it is not too small rather than too large as compared with the war protection essential for its great merchant marine.

THE DIFFICULTY OF SECURING A RESERVE BODY OF MEN CAPABLE OF BEING TRAINED TO NAVAL DUTIES.

As in the case of the army, the reserve of men for naval needs must come from the country at large. It would be just as logical for the military authorities to rely upon the militia as a needful reserve for war purposes as it would be for the naval administrators to depend upon the merchant marine for supplying the reserve requisite for naval needs.

The mercantile marine of the several countries will also prove disappointing as a source of supply of men by reason of the large number of aliens serving in the ships of the leading maritime countries. The British ships contain thousands of Chinese, Japanese and Lascars, and in time of war these men will have to be replaced by British subjects, or else the laying up of some of the ships will occur.

The Danes, Swedes and Norwegians can be found in large numbers in German, American and English ships, and it will not be surprising if the national spirit of these seamen will be a determining factor in their decision as to how they will act in time of a great war. It may thus be easier to get ships than secure the necessary men to man them.

The question of securing a reserve of efficiently trained men for battleships and cruisers is one of extreme importance in modern warfare. The conditions of the hour of battle on board the war vessel are very different from the conditions existing in time of peace. There is not a naval power in the world which is not at the present time short of an adequate complement of trained men. Under cruising conditions, when only a portion of the boiler and engine power is used, when hatches are opened and when the majority of the vessels cruise in northern latitudes in summer and semi-tropical waters in winter, the health of the crews is all that is desired. The war vessel is, however, anything but a sanitarium during time of war, particularly if the ship is kept in readiness to meet anything like an equal foe. Then will come an inevitable large sick list, and unless there is a reserve of trained men to maintain the full complements of the vessels, the fighting efficiency of the ships themselves will become seriously impaired.

OUR RESERVE OF TRAINED MEN MUST POSSESS ENGINEERING INCLINATIONS AND MECHANICAL ABILITY.

It is not so much an acquiring of the habit of the sea as it is the possession of engineering inclinations that are requisite for the modern man-of-warsman. In the operation of the various mechanical appliances that are now installed on board the warship, it is a technical rather than the

nautical training that must be secured. The three great manufacturing nations—England, Germany and the United States—thus possess an inestimable military advantage in their ability to secure in time of war the reserve of men needful for naval purposes.

While the merchant marine of a nation might furnish some comparatively well-trained men in time of war for naval vessels, it must be remembered that at such time the demands of the merchant marine itself for training men greatly increases. Then again, as quite a large number of merchant vessels must be secured as auxiliaries to the fleet, it is highly improbable that all the men secured from the merchant service would be more than sufficient to man these ships. The value of the merchant marine, therefore, as a source of supply for naval needs in time of war is more apparent than real. Compared with the necessities of a nation, the carrying capacity of the merchant marine of any country can be easily taxed, and there are hundreds of tramp steamers that now traverse the various oceans that would have to seek port in case they were liable to seizure by the cruisers and scouts of a possible enemy. The fostering of a merchant marine should be looked at from a military standpoint, and those who are interested in the revival of our maritime industry would probably secure better success if more consideration was given to this phase of the problem.

The experience of the war with Spain conclusively showed that skilled mechanics, with excellent powers of observation, do not require a long period to be trained for efficient duty, either in the turret or in the engine-room. It should be recognized that the great body of men for naval needs, in case we ever get into war with a strong power, must come from the iron or metal workshops, engine-rooms and fire-rooms on shore. The capability of the artisans of different nations to adapt themselves to technical naval duties may be the real test of strength for sea power, and certainly in this respect we ought not to believe that any nation is our superior.

THE QUESTION OF TRANSPORTATION OF EXCEEDING IMPORTANCE.

The purpose of Great Britain in considering the coast line of every possible enemy as one of her military frontiers has caused the conduct of war to be more dependent upon methods of business than principles of strategy. The most difficult problem that confronted President McKinley in the management of the Spanish-American war was the devising of means to transport the troops, horses and supplies of General Shafter's army. It was likewise the problem of transporting troops and munitions of war to the Philippines that was not only the most expensive, but the most troublesome matter to be handled in insuring peace in those islands. The actual fighting was nothing as compared with the business problem. The fact that we are likely to spend several hundred million dollars in establishing peaceful conditions in the Philippines shows that the question must be regarded as a business one.

The problem of transportation was the most difficult one confronting the British Admirality and War Offices in the crushing of the Boers. It required months to assemble the necessary ships and fit them as transports for conveying an adequate number of troops to South Africa. There was comparatively little for either Lord Roberts or Kitchener to do after the transportation problem had been solved.

Where armies must march but a short distance to the field of battle, as the Germans did in 1871, the transportation question may not rise to as supreme an importance, but in the conduct of naval operations it is absolutely essential to consider the problem as a serious one. The naval power, therefore, which possesses facilities for rapid and extensive transportation of men and material, is in many respects well prepared for war.

While we may have but few ships engaged in the foreign trade, we possess a good-sized fleet of coastwise steamers, some of which could be quickly used as auxiliaries to the fleets protecting our coast.

If there is one particular advantage that we possess over our commercial rivals, it is in the economy and rapidity

with which we are able to handle material. In cranes, conveyors and engineering appliances we are in the front rank. In methods of conveyance such strides have been made that we have changed the conditions affecting the carrying of supplies, and, as a result, there has been made possible by our superiority in handling material, not only the lowest freight rates, but the quickest dispatch for long hauls. Any hostile fleet, therefore, attempting the blockade of either a Gulf or Atlantic port, will find the manufacturing resources of even the Mississippi Valley at the early command of our military and naval authorities. The possession of vast and superior transportation facilities by our military forces will make possible the building of temporary forts, and the repair of war vessels in a surprisingly short time. The cost of this hurried work may be enormous, but every continental nation recognizes the fact that in times of emergency we are ready to indulge in such an outlay, and thus the problem of blockading our coast is one of such magnitude that it is practically beyond the possibility of any single power. It is the reserve of resources rather than the line of forts, or the fleet of battleships, that will be the great deterrent for some decades, at least, to any attack from Europe. It will be the clink of the bankers' gold that will tell the tale of the battles lost or won.

OUR RESERVE OF MEANS AND MONEY A SHIELD OF DEFENSE—OUR NAVY A WEAPON OF OFFENSE.

From time immemorial the individual, as well as the nation, has been obliged to provide both a shield and a weapon for either offensive or defensive purposes. It is our agricultural, mineral, manufacturing and financial reserve, combined with our power to utilize such latent resources, that constitutes the best shield of national safety. While it is true that China may possess great wealth of agricultural and mining resources, the lack of transportation facilities in that country makes it impossible to utilize such resources for either national safety or the public good.

A great army and navy may be the only possible weapon for offensive work. If it be good military policy to make

the enemy's coast the first line of our national defense, then there should be a strengthening of both services. As wars seem inevitable, every nation should be prepared to strike the first blow. A hundred millions invested in cruisers and battleships may save the expenditure of ten times that amount in drawing upon our latent resources as a shield of defense. Our navy is not as strong as it should be, but the increase should be progressive. The naval service, however, should always keep in mind the fact that there are aggressive individuals high in authority in every naval service who are too desirous and too prone to use any weapon that is placed in their hands, and thus there is a prejudice existing against the building of a strong navy that must ever be recognized.

The demand for an increase in naval strength should best come from those without rather than from within the service. The most striking fact in connection with the rehabilitation of the American Navy has been the enthusiastic and consistent support of the people of the Middle West to an increase in naval strength. Until recently but few recruits came from that section, and the manufacturing interests between Pittsburg and Denver received but little, if any, direct financial benefit from the building of either ships, machinery or guns. Strange as it may seem, the wavering in the desire to augment our naval strength has come from the Atlantic and Pacific Coasts; the representatives from those sections at times being more desirous of having the Government engage in various internal improvements and the rehabilitation of the merchant marine than in strengthening our fleet of battleships. It is because, I believe, that the real interests of the Navy can be best subserved by pointing out the great shield that we possess in our latent resources rather than by attempting to tell of the weakness of our Navy as a weapon, that I have dwelt upon the strength of the shield rather than upon the weakness of the weapons of national strength.

THE OPPORTUNITY OF AN ENLISTED MAN RECEIVING A COMMISSION SHOULD BE INCREASED.

The best work that the Navy itself can do is to increase the efficiency of the organization. There should also be an earnest effort made to bring the Service in closer touch with the people. While the affection of the country for the Navy has progressively increased during the past ten years, there is a strong and deep feeling prevailing that the Service is too exclusive, by reason of the fact that it is not as easy for the average young man to secure a commission in the Navy as it is in the Army. Since the retirement of General Schofield from the command of the Army, nearly all the general officers of the Army, who commanded troops in the field, entered the Service as a volunteer and won their commissions by sheer merit. The military and administrative service performed by such generals as Miles, Brooke, Young and Chaffee justify the entry of young men into the regular army as commissioned officers who are other than graduates of the West Point Military Academy. The gate to a commission in the Navy should be opened wider, and I know of no better way of bringing such action about than by permitting the graduates of technological schools, who possess military aptitude and inclinations, to compete for commissions in the Service. The curricula of at least a dozen scientific schools, from a scientific standpoint, is the equal, if not the superior, of the Annapolis institution.

The work of the modern naval officer is to a great extent technical, and surely such must be the case in the junior grades. The work of the ordnance and electrical expert in both Army and Navy is not widely separated from that of the mechanical. In fact, the measure of one's success in ordnance and electrical lines is simply proportional to his technical inclinations, study and training.

OUR TECHNOLOGICAL UNIVERSITIES CAPABLE OF SUPPLEMENTING THE WORK OF THE NAVAL ACADEMY.

The question of utilizing the engineering colleges for the training of officers for the Army and Navy, and thus bringing both Services in closer touch with the people, is not a

new proposition. In writing upon this subject only a short time ago, I presented the following views, which received the cordial endorsement of General Miles, then commanding the Army, and of General Corbin, executive officials whose military experience in both the Civil and Spanish-American wars particularly qualified them for giving expression as to the capabilities of the graduates of our engineering colleges to qualify for such work:

"The Army and the Navy will require for war purposes more officers than West Point and Annapolis can supply. It is hardly possible that Congress can be induced to enlarge these schools to the size demanded by the Nation's requirements. As many competent officers must be secured for both the Army and the Navy from sources outside Annapolis and West Point, it is my belief that these military necessities can be met by calling upon the technological colleges to perform the duties which are within their power, and which in honor they are bound to undertake. In order to secure a sufficient and effective directing personnel for the Army and the Navy, it has been proposed to commission, from the graduates of the technological colleges, those young men who are able to complete successfully a course of technical and military instruction prescribed by officials of the Government.

"The military question is in many respects an engineering question. There are a hundred scientific colleges in this country which are capable of giving instruction necessary to fit their graduates for important engineering duties; and it is not unreasonable to presume that a majority of these institutions could give military instruction if substantial inducement were offered for carrying on the work. During the Civil War some of the most valuable of the naval engineer officers had been those who had been trained as civil engineers. The training of these men had been well grounded along engineering lines, and by observation and attention to duty, the work incident to a naval career soon became familiar to them.

"There are engineers in Europe, as well as in America, who are controlling and directing more employees than are

comprised in the entire personnel of the United States Navy. An engineering mind is an analyzing, directing and military mind, and it can be employed for the accomplishment of strategical and tactical movements. The rapidity with which an army corps can be moved may decide the destiny of a nation; and the success of this work, under existing conditions, is more likely to be dependent upon the superintendent of a railroad than upon a military commander. The executive ability of the managing engineers of our great industrial plants, in expeditiously furnishing munitions of war, may be of greater benefit than the enrollment of an army corps.

"The requirements of the Army and Navy as regards commissioned officers cannot be met by Annapolis and West Point. The work can be carried on only by many technological colleges of the land, under the direction of master minds acquainted with our military needs and having some knowledge of the power and influence of university work. Under the control of the Secretary of War and of the Navy, there should be efficient and thorough supervision of this scientific and military education; and the maintenance of all such educational courses should be carried on in a manner satisfactory to the Government. If this were done, it would be a step in the direction of co-ordinating American universities and colleges, It would raise the standard of the inefficient institutions by stimulating emulation and encouraging a comparative study of different methods of instruction. Scientific instruction of a high grade is already provided by numerous technical institutions in many parts of our country. The range and quality of their work have immeasurably advanced within the last few years, and several now take rank with the best institutions of their kind in the world. These colleges have made wonderful strides along educational lines, and their faculties make the proud claim that their graduates are the equals in culture and intelligence of those sent out by the colleges of liberal arts.

VIEWS OF COLLEGE PRESIDENTS AS TO THE MILITARY DUTY OF THEIR INSTITUTIONS.

"During the last ten years I have discussed this question with distinguished educators, prominent statesmen, and able military leaders, and it seems to be the general opinion that the good of the nation demands that some such action should be taken. One distinguished Southern educator declares 'such a measure would be founded upon patriotism and common sense.' The lamented General Francis A. Walker, of the Massachusetts Institute of Technology, who was very earnest in his desire to have his institution perform some military duty for the nation, in writing to me upon the subject, said: 'Whether looked at from the point of view of one interested in the political, military, or naval history of our land, the subject concerns the defense of the country.'

"At least threescore of college presidents have been consulted in regard to the general work of bringing their institution to a clearer sense of their military obligations to the State. It is practically their unanimous testimony that the work is not only in the interest of sound technical education, but that the greatest beneficiary would be the National Government. When such conservative forces are aroused to the necessity of this work, it must be manifest that it is of import to the nation. It is of marked significance that this proposition appeals most strongly to those college presidents and professors who were formerly identified with either the military or the naval service. These men, from personal experience and association, realize that mutual benefit must be secured by bringing all scientific institutions in closer touch with each other and with the military and naval authorities.

A NATIONAL COMMISSION SHOULD BE APPOINTED TO INVESTIGATE THE MILITARY POSSIBILITIES OF ENGINEERING INSTITUTIONS.

"It is, therefore, time for a plan to be formulated whereby the engineering institutions can render the important military duty to the nation that is within their power to accom-

plish, and that ought to be within their desire to perform. As it is to be expected that Congress will be more inclined to follow than to attempt to direct public sentiment upon this question, the matter must be taken in hand by the immovable sanity of military officials and scientific educators. A joint commission composed of two officers of the Army, two of the Navy, two representatives of the land-grant colleges, and two representatives of other scientific institutions, with some former Secretary of War or the Navy as chairman of the body, should be appointed. Within a year this commission could formulate a scheme whereby the scientific institutions of the United States could supplement the work of West Point and Annapolis, and whereby it would be possible to secure for the future a reserve of highly trained technical men who would receive at least the principles of a military education.

"Even to meet the issue of war with Spain we had to increase our army tenfold. It is well known that, despite the enormous advantages that we possessed over our foe, we had to keep our troops for months in camps of instruction. In fact, it took so long to work these volunteer regiments into shape that the army which besieged Santiago was practically composed of a good part of the regular army, and but few regiments of volunteers. Such delay would have been, in part, obviated if our engineering institutions had done the military duty that was within their power, and if the nation had utilized the educational forces that were within reach.

"The National and State Governments expend millions of dollars in training a volunteer force, and the primary purpose of establishing such an organization is to have in readiness at least a partly trained reserve for the needs of the nation. It is, therefore, necessary, as well as logical, to train a reserve of officers; and there seems no better way of securing this desirable result than by utilizing the great resources that are possessed by the educational institutions of the land.

"If this proposition were fully understood, it would appeal to the young men of America now receiving instruc-

tion in the several colleges of mechanic arts and sciences. These young men are strong in their own self-respect and ambition, and are intense in their love of country; and, if necessary, their conscience will impel them to offer their all for the honor of the nation. Their education should be directed so that the best within them can be brought out; and I know of no better way of training them to become noble men and valuable citizens than that they should be made to realize that they are receiving a military as well as technical and liberal education for life's work, while in the glory and strength of young manhood."

THE CALL OF THE COMING CENTURY IS FOR THE TRAINING OF THE LARGE CONTINGENT OF EXECUTIVE TECHNICAL LEADERS.

The military call of the coming century will be a demand for the elect of those trained to executive-technical work to qualify themselves so that when the call to arms comes they may be fitted to assume military responsibilities.

The nation has increased sixfold since the establishment of West Point, and threefold since the organization of the Naval Academy, and it will act as a spur and incentive to both institutions to have their work shown up with the best of the technological institutions.

Instead of calling upon all young men of the country to perform military service as in the case of some continental countries, it should be our aim to compel every technological institution receiving direct or indirect national aid to perform the service of training leaders for the military necessities of the future. Where there is an abundance of leaders, there will be no difficulty in increasing the army greatly without, to a great extent, impairing efficiency.

THE DESTINY OF EVENTS WILL COMPEL US TO EXERCISE PARAMOUNT RIGHTS IN CERTAIN WATERS.

It may be that this nation may be free from war for many years, but where a nation asserts certain doctrines that interfere with the colonization projects or commercial rights of rival powers, the maintenance of such doctrine

can only be done at times by force of arms. From time immemorial nations have asserted paramount rights over adjoining buffer states, over environing seas, and our entrance as a world power has made it necessary for us to protect domains beyond our own coast. Force of circumstances will compel us to assert a paramount right in the West Indies and the North Pacific. We must either build a navy capable of maintaining this claim, or else sacrifice foreign trade that is a necessity to the disposal of our surplus agricultural and manufactured products.

The fisheries and gold deposits of Alaska and Aleutian Islands will compel this nation, at a very early day, to reassert the claim that Behring Sea is a closed ocean, and that we have and will exercise a paramount right in regulating the traffic of the commerce of that body of water. The following views, although expressed upon the subject of an interoceanic canal, are exceedingly applicable to the policy that should be formulated in regard to our position of the Pacific.

"The Pacific Ocean is an expanse of magnificent distances. Neither over the lands of any empire, nor over the 'barren foam' of any other sea, can one traverse so many leagues without crossing the border, as upon its waters. Its area is two-fifths that of the whole surface of the globe, and more than two and one-third times that of the Atlantic, with all its tributary seas. In the distribution of the land within its limits, the Pacific presents marked contrasts. Its southwestern area is a vast and tangled cluster of islets, islands, and archipelagoes, culminating in continental Australia; its eastern and northern portions are but an ocean desert, 'where gloom the dark, broad seas' alone, save for such fair oases as Hawaii.

"Conquest, treaty and an imperial purchase have given the United States a position, clearly paramount, on the Northern Pacific. The boundaries of the Republic reach so far across these waters that, between eastern Maine at one extremity to the farthest of the Aleutians at other, as measured by longitude, the geographical center of its territory lies westward of the Golden Gate. The Pacific States have

a seaboard equal to that of the Gulf, and but one-tenth less than that of the Atlantic, while Alaska and the islands have a coast line more than eight-tenths that of all these three combined.

"From the southern limit of California, at 32° 28′ north, this ocean is, on its eastern and northern sides, bounded by American territory, continental or islandic, unbroken save by the short link of British Columbian coast, and reaching through nearly three-fourths the longitude from California to Japan.

"It would seem, then, that the North Pacific is, in effect, an American ocean, and that the United States should hold, in Nature's fee simple, the title to a sphere of influence there, to a paramount control. This right is not tangible in law, nor recognizable by treaty, but it is yet inherent through the possession of an imperial territory which bounds, almost wholly, these northern waters, which looks to them for commercial outlet, and which from them is susceptible of attack in war."

RADIUM AND TERRESTRIAL HEAT.

Professor Rutherford, of McGill University, Montreal, in a lecture before the Royal Institution in London, has advanced the striking theory that the earth's heat is not attributable to a molten mass that has been slowly cooling for a million years, which has been the generally accepted theory, but to the presence of radium. Professor Rutherford's address was listened to by a distinguished audience, including Lord Kelvin, Lord Rayleigh, Professor Dewar and other great scientists. Professor Rutherford was the first to measure the mass and velocity of the electrons of radium. He announced the probability of radium being contained in all matter.—*Electrical World.*

BRAKE EFFICIENCY ON MOTOR CARS.

The results of some trials made by the French Automobile Club to ascertain the distances at which motor cars can be stopped when running at various speeds are likely to upset the popular impressions formed by many motorists that a car can be brought to a standstill in its own length from a speed of 30 miles an hour. The trials in question were conducted in the Bois de Boulogne, and while they show that motor cars can stop quicker than horses, yet they required a distance of 10 feet in which to come to rest when traveling at a speed of 7½ miles an hour. At a speed of 10 miles an hour they stopped in 13½ feet, and at 12½ miles, in 16¾ feet. At 16 miles an hour, 33⅓ feet were required to stop in, and 60 feet at a speed of 25 miles an hour.—*Scientific American Supplement.*

Taylor's Absorption Process for Butter-Making.

[*Being the Report of the Committee on Science and the Arts on the invention of Charles M. Taylor, Jr.*

Sub-Committee: Samuel P. Sadtler, Chairman, F. A. Genth, Edward Woolman, George Malony.]

[No. 2276.]

The Franklin Institute of the State of Pennsylvania, acting through its Committee on Science and the Arts, investigating the merits of Taylor's Butter-Making Process, reports as follows:

The Taylor butter process, which has been been brought before the Science and Arts Committee of the Franklin Institute for examination, is a process for effecting by simple and inexpensive means, the rapid separation of the fatty particles of a sweet cream from the watery solution of the proteids, sugar and inorganic salts.

For this process, the invention of Mr. Charles M. Taylor, Jr., of Philadelphia, both United States and foreign patents, including English, French, German and Canadian patents, have been granted.

The principle upon which the invention of Mr. Taylor is based is the absorption by sheets of blotting-paper of the watery liquid, while the fatty particles remain upon the surface. After a sufficient length of time has elapsed, the fatty layer can be rolled together, separating quite readily from the moist blotting-pad. Mr. Taylor has, after much experimenting, found that heavy white sheets of blotting paper, supported upon absorptive material like Turkish toweling, placed in shallow pans, furnish the best material for use with his process.

His procedure is outlined in the words of his letter of application:

"Sweet cream is poured in through these absorptive paper separators, which are permeable to the watery constituents of the cream, but impervious to the butter-fat and solids, which form in a layer about one-quarter inch thick

on the surface of the paper. The absorptive pads, which are in contact with the paper, take up, by capillary attraction, most of the caseous and watery constituents.

"The cream may be placed in the refrigerator over night, and in the morning the butter is ready to roll off the paper. The butter may be used fresh without working, or can be salted to taste and worked like ordinary churned butter. The time of absorption requires about from three to four hours."

The advantages claimed for this invention by the patentee are:

(1) Less labor than churning, the chief work being the washing of the absorptive pads. These pads will last six months or longer in daily use.

(2) No expert knowledge is required in ripening the cream, as sweet cream only is used, thereby securing a pure, sweet butter equal to the best cream butter made.

(3) A much larger percentage of butter can be made from the same quantity and quality of cream than by churning, experiments showing this increase to be from three to ten per cent.

(4) When salted, the keeping qualities of this butter are excellent, and it will remain sweet a week longer.

(5) Families can make their own butter daily, and rest assured that they are not using oleomargarine or renovated butter.

(6) Farmers who now sell their milk at 3 cents a quart can convert the cream into butter at a large profit.

The Committee, after seeing the process carried out by the inventor and examining and analyzing the samples of the separated fatty layer, and of the butter made from this by working out the buttermilk and salting, have come to the following conclusions:

First.—The process is a very neat and efficient mode of separating the fatty portions of cream from the watery portions. Analysis of this fatty layer showed: Fat, 79.49 per cent., and casein, 2.55 per cent.

The fat percentage here is higher than obtainable by the centrifugal separator, although the casein percentage is not better than with centrifugated cream.

Second.—This separated fatty layer, if taken for immediate table use, is very palatable in taste. It does not keep satisfactorily, however, for any length of time unless the watery solution of casein is worked out of it by kneading, and the resultant butter salted. Analysis of the kneaded or worked butter made by Mr. Taylor showed: Fat, 82.95 per cent. and casein, 1.15 per cent., which indicates a distinct improvement over the raw fatty layer which had not been worked.

Third.—The product of the blotting-pad absorption is therefore not a true or normal butter as yet, because of the high percentage of casein still present; and the consequent lack of keeping quality. It seems to stand in composition intermediate between a Devonshire clotted cream and a true worked butter.

Fourth.—The product when finished by working or kneading is of a high degree of purity. In the finished sample analyzed, the Reichert-Meissl value was found to be 30.31, which is equal to the best found in any butter. It is therefore not to be classed with such products as butterine, or renovated butter, but is a true butter answering all tests and coming up to the best standards.

The Franklin Institute accordingly recommends the award of the John Scott Legacy Medal and Premium to Charles M. Taylor, Jr., in recognition of the merits of this invention.

Attest: WM. H. WAHL, *Secretary.*

Notes and Comments.

TEMPERING COPPER OR COPPER ALLOYS.

The process of tempering copper or its alloys described in the *Zeitschrift für Werkzeugmaschinen und Werkzeuge* (Journal for Machine Tools and Tools) consists in heating the metals in question for a time at the requisite temperature, sprinkling them while in a heated condition with sulphur, and then plunging them hot into a bath of blue vitrol. It is advisable to reheat the metal before it has become quite cool. Numerous experiments have shown that the new tempering process is specially suitable for alloys of copper, and that remarkably good results can be obtained by treating an alloy of copper and tin by the process just described. Any of the various alloys of

copper can, however, be used, the choice depending of course upon the nature of the article for which it is intended. The copper or alloy is usually put into the required shape (e. g., a wheel or tool) before tempering. The castings are then heated for a suitable time, say three minutes, over a fire, preferably a charcoal fire, at the proper temperature. The best results are obtained when the temperature is raised to the melting point of tin. The articles are placed on the fire and, together with the neighboring blocks of charcoal, sprinkled with powdered sulphur, till they are entirely covered by it, the sulphur-vapor thus being brought into contact with the castings. It is best to add the sulphur when the articles are thoroughly heated. After being covered with the sulphur the castings remain in the fire for a time; they are then plunged hot into a solution of blue vitriol, and allowed to remain in it for a short period. When the castings are taken from the vitriol, it is well to reheat them, and allow them to cool without the intervention of a cooling mixture. The new method of treating copper and its various alloys produces a remarkable hardness without impairing the ductility of the metal, thus rendering it specially useful for purposes for which a high degree of hardness and, at the same time malleability, ductility and toughness are required.—*Scientific American Supplement.*

ELECTROLYTIC METHOD OF ESTIMATING GOLD.

At a recent meeting of the Faraday Society, Dr. F. M. Perkins and Mr. W. C. Prebble gave the results of researches to arrive at an electrolytic method of estimating gold which should be perfectly accurate, and yet far more rapid than the ordinary double cyanide method which the authors, differing from Classen, consider inordinately long, even in hot solutions. Solutions of sodium thiosulphate, cyanide, sodium sulphide, potassium thiocyanate and ammonium thiocyanate were all tried and the results compared. The first-named was useless; of the others—which are all accurate—the thiocyanates gave the best results and the ammonium salt was better than the potassium. With currents of 0·2 ampere per square decimeter, the deposition of 0·05 to 0·08 gram of gold was complete in five or six hours. With a current of 0·4 to 0·5 ampere, 1·5 to 2 hours sufficed. The presence of a little persulphate considerably reduced the voltage required. Experiments were also made to determine the best method of removing the deposited gold. Chlorine or bromine water was satisfactory, but slow; aqua regia was risky; the authors recommended a 2 per cent. solution of potassium cyanide containing a little hydrogen peroxide or a persulphate. One or two minutes then sufficed to remove the gold.—*Scientific American.*

CENSUS OF THE FLUORSPAR INDUSTRY.

The mining of fluorspar has increased over 500 per cent. during the past decade, owing to the greater use of this mineral in metallurgical processes, especially in the iron industry, according to a special report compiled for the Twelfth Census, soon to be published. The first statistics of production were collected at the Eleventh Census, and these are compared with the statistics for 1902 in the following table:

	1902.	1889.
Quantity, short tons	48,818	9,500
Value	$275,682	$45,855

Of the twenty-two mines in 1902, fourteen were in Kentucky, five in Illinois, two in Arizona and one in Tennessee. In these twelve years Illinois, which was the only State producing fluorspar commercially in 1889, has increased its production from 9,500 to 18,860 tons.

In the fluorspar deposits of Illinois and Kentucky there is known to be a very large supply of this mineral, capable of meeting the demand for many years. As this overcomes one of the objections often advanced against using fluorspar in the smelting of iron—namely, that a constant supply of this mineral could not be depended upon—its use for this purpose should now increase rapidly. Thus far the larger proportion of the fluorspar mined has been used in steel works. Very little is used in blast furnaces or in the smelting of copper or other metals; for these purposes, and also in foundry work, its use will undoubtedly increase rapidly when its value as a flux is more thoroughly understood.

The average value per ton has varied from $4 to $8. The average was exceptionally high in the years 1896 to 1898, inclusive, reaching $8.21 in 1898. In 1902 it was $5.66; the prices reported for that year varied from $2.86 to $11.50 per ton, this higher value being obtained for the fluorspar mined in Arizona, which was used in California.—*Iron Age.*

PROCESS FOR HARDENING IRON.

A new process for hardening iron has been developed by two Prussian inventors, according to the *Engineer.* It consists in adding to iron a small percentage of phosphorus combined with a large amount of carbon. The iron is heated in a tempering powder consisting of bone dust, to which are added 300 grains of yellow prussiate, 250 grains of cyanide of potassium and 400 grains of phosphorus. The receptacle is closed and luted with clay, and raised to a clear red or white heat. The material treated is then taken out and plunged, while still hot, into a warm bath. It is claimed that this will harden the surface of a piece of iron weighing 400 pounds to a depth of about 0·04 inch, and that the iron can neither be cut nor chipped by the best steel used, and that it can be readily welded.

A CHANGE IN BRITISH PATENT LAWS.

A radical change in the granting of patents will go into effect in Great Britain on the first day of next year. The British patent laws as they now stand have been very unsatisfactory to both inventors and the public, because a patent has always been granted at the risk of the applicant, without any efficient search being made into the originality of the alleged invention. Complaint was made that patents which had absolutely no right to exist were too frequently used for the purpose of levying blackmail on manufacturers and others interested in goods manufactured under patents which were valid. The inventor has been given no warning whatever that his supposed invention was in reality no invention at all. Naturally a patent had much less value

under such a system than it would have under the patent laws of the United States, Germany and some other countries. As a consequence of repeated complaint, the British Board of Trade appointed a commission made up of eminent men to investigate the question, and as a result the patent law of 1902 was passed. The important clause relating to examinations was not made immediately operative for various reasons of expediency, but now the Board of Trade has set the approaching January 1 as the date of the beginning of a new order of things in the British patent office.

The commission did not look with entire favor upon the American system, the principal objection being that too much power is given the patent examiner, who has to act as both advocate and judge, as the *Engineer* puts it. Too much is placed on the judgment of this one man. Another defect brought out was that no intimation is given the applicant of the extent of the examination, and the search must of necessity be imperfectly carried out. Consequently a sort of compromise was selected as the best system to be applied in Great Britain.

Under this new law the British patent office cannot refuse to grant a patent, but it can so label it that it will be apparent to all that the idea in question lacks originality. It will be the duty of the office to make an investigation for the purpose of ascertaining whether the invention claimed in any complete specification has been claimed or described in the specification of any British patent within the fifty years next before the date of the application. It will thus be seen that the scope of the search is strictly defined, but this search is to be thoroughly made, so that any one who afterward desires to continue the investigation may begin where the patent office left off. In most cases the fifty years will be sufficient, for the present, at least. Ten or twenty years from now it will probably be necessary to extend the scope of the examination to sixty or seventy years, or it may be extended in a few years to make the search more thorough, dating back from the present year as the basis. No power of refusal is given under the act. But when any prior specification is found which appears to anticipate the applicant's invention, it will be the duty of the comptroller of the patent office to inform him of the objection and to give him the opportunity to amend his application so as to make it clear that he is not seeking to claim what is not new. And then, and here comes the protection to the public, unless the objection be removed it is the duty of the comptroller to decide "whether a reference to any, and if so what, prior specifications ought to be made by way of notice to the public." In other words, the duty of the comptroller will be to bring out in the patent itself the fact that the invention, so called, is not really an invention at all. The specification will bear on its face what has gone before, which will protect the legitimate inventor from the tricks of those who would use the patent office to further dishonest schemes.—*Iron Age.*

MUNICIPAL STEAM-HEATING IN DRESDEN.

An interesting application of the steam-heating system so extensively adopted in this country is in course of experiment in Dresden. In that city the Saxon Government has established a huge central station, and from this the heat is distributed among a number of the municipal buildings, including

the Royal Opera House, the Picture Gallery, Zwinger Museum, the Hofkirche, and Royal Palace. The edifices are all situated near the central heating station, which stands upon the banks of the river Elbe, whereby an adequate supply of water is always available. The station contains ten generators, producing over 55,000 pounds of steam per hour. The steam is distributed to the various public buildings by means of steam pipes laid beneath the streets. But this ingenious heating system is also utilized to fulfil a dual purpose—the generating of electricity for lighting the various edifices. The heat is generated and distributed during the early morning, when the electric supply is not required, and once the buildings are thoroughly heated, it requires but very little pressure to maintain the temperature desired throughout the day. Consequently, this arrangement enables the steam power generated during the later part of the day to drive the electric installation and maintain the pressure required. This combined heating and electric-lighting system has proved highly successful and economical, and its extension to other towns in Saxony is contemplated.—*Scientific American.*

BAMBOO.

The word bamboo suggests to most Americans a faithful fishing-rod or a dainty fan. To the Japanese and Chinese, who are the most practical agriculturists in the world, it is as indispensable as the white pine to the American farmer. They are not only dependent upon it for much of their building material, but make their ropes, mats, kitchen utensils and innumerable other articles out of it. There are many varieties of the bamboo plant, from the species which is woven into mats to the tall bamboo tree which the Chinaman uses for the mast of his large boat. One variety is cultivated as a vegetable, and the young shoots eaten like asparagus, or they may be salted, pickled, or preserved. The rapidity of growth of the bamboo is perhaps its most wonderful characteristic. There are actual records of a bamboo growing 3 feet in a single day, or at the rate of 1½ inches an hour. Varieties of bamboo are found everywhere in Japan, even where there are heavy falls of snow in winter. It is a popular misconception that bamboos grow only in the tropics. Japan is a land of bamboos, and yet where these plants grow it is not so warm in winter as it is in California Some of these varieties could be grown commercially in the United States.—*David G. Fairchild in the National Geographic Magazine.*

STEEL CHIMNEYS.

W. W. Christie, in the *Engineering News*, reports the following as among the high steel chimneys in the United States: Nichols Chemical Company, Brooklyn, N. Y., 310 feet high, 35 feet in diameter at base, 12 feet at top; Pennsylvania Salt Company, Natrona, Pa., 225 feet high, 10 feet flue diameter; Maryland Steel Company, Sparrow's Point, Md., two chimneys, each 225 feet high and 13 feet inside diameter. It is noteworthy that all these are at metallurgical plants. Also, the highest two brick chimneys are at metallurgical plants; the old Grant smelter at Denver, Colo., and the works of the Orford Copper Company at Constable Hook, New York Harbor, each of these being about 350 feet in height.

SIEMENS & HALSKE ELECTROLYTIC PROCESS FOR COPPER.

The Siemens & Halske process of copper extraction consists in leaching finely pulverized, roasted ore at 90° C. with ferric sulphate solution, containing free sulphuric acid. The ferric sulphate is reduced to ferrous, and copper is dissolved as sulphate. Electrolysis of the solution in a diaphragm cell gives copper at the cathode, and oxidizes ferrous sulphate to ferric at the anode. This is an old process, having been described in British patents 14,033 of 1886, and 3,533 of 1889. M. DeK. Thompson, Jr., has studied the reactions (*Electrochemical Industry*, 1904, II, pp. 225–231). Raw copper pyrite is not appreciably attacked by ferric sulphate, but after roasting is readily soluble. Copper can be deposited from an acid solution of ferrous and copper sulphates until the concentration reaches a low value; that is, with a current density of ·47 amperes per 100 square centimeters until the concentration of copper in solution is ·5 per cent., at which point spongy copper begins to form. Using carbon electrodes, the oxidation at the anode is at first very efficient, but as the concentration of ferrous sulphate decreases the process gradually falls off in efficiency.

Book Notices.

Machine Design. Part I: Fastenings. By William Ledyard Cathcart, Adj. Prof. Mechanical Engineering, Columbia University, M. Am. Soc. M. E., etc. (Large 8vo, pp. xi + 285.) New York : D. Van Nostrand & Co. 1903. (Price, $5.00.)

This work has been designed by the author to present in concise form, for the use of the student and designer, modern American data based upon the best practice in the branch of machine design to which it refers.

The subjects treated are arranged under the following chapter heads: Shrinkage and Pressure Joints; Screw Fastenings; Riveted Joints (Theory and Formulæ); Riveted Joints (Tests and Data from Practice); Key Joints; Pin Joints. The text is snpplemented by no less than 77 tables.

The theoretical treatment of the subject has not been neglected.

The author has apparently thoroughly modernized his work, bringing the consideration of the subjects discussed up to date. In this respect the chapter on Screw Fastenings is noteworthy.

The work is fully illustrated and well printed. W.

Le Droit International, les Principes, les Théories, les Faits. Par Ernest Nys, Conseiller à la Cour d' Appel, Professeur à l'Université de Bruxelles. Bruxelles : Alfred Castaigne. Paris : Albert Fontemoing. 1904.

The last chapter of this valuable book is entitled "Le Domaine Aérien," and in it Judge Nys ably deals with the prospective application of International Law to the right of nations to the air above their countries. The development of aërial navigation, of flying machines and dirigible balloons, may be expected to bring to the fore in the future the question as to whether, as is generally held now, the rights of a State stop overhead at the distance of a cannon-shot from the ground, or whether, as seems most just, these rights extend indefinitely into space. E. S. B.

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ELECTRICAL SECTION.

Stated Meeting held Thursday, March 31, 1904.

Electrolytic Receivers in Wireless Telegraphy.

BY DR. LEE DE FOREST.

With the form and nature of the ordinary filings-tube coherer as applied to-day in wireless telegraphy the public has become fairly familiar.

Branley, the distinguished French physicist, discovered in 1891 that the effect of electrical oscillations upon a body of metallic filings, or dust, was to produce a sudden increase in the conductivity of the mass, a conductivity which persisted until the particles were broken apart again by mechanical jar.

Although the American, Varley, the English scientist Hughes, and especially Onesti, the Italian, had previously noted this phenomenon, none of these investigators had fully appreciated the causes involved, or given to the world of science the benefit of their researches in thorough published reports.

The discovery of the "coherer" therefore is rightfully attributed to M. Branley; but to Professor Popoff, of St. Petersburg, and to Sir Oliver Lodge, of England, must be given the credit of applying the relay and mechanical tapper to the filings tube, the addition of antennæ wings, of upright wire and earth connection, and the first steps towards refinement and an appreciation of the possibilities of the new detector as applied to an unborn branch of human enterprise and progress.

With the notable work of Marconi in still further adapting the Popoff-Lodge arrangement to commercial requirements, the gradual increase of distance on which aerographic communication was established, the ingenious improvements in coherers by such men abroad as Tissot, Ducretet, Castelli, then by Lodge and Branley themselves, and in this country by Shoemaker, the audience is more or less familiar.

Enormous is the bulk of research matter published regarding the coherer. Theories of the action involved have been numerous, but divided chiefly into two schools: First, that of Lodge, who demonstrated an actual *welding* together of metallic filings, after the same had been drawn into contact by the electro-static attraction of the opposite charges induced upon the faces of the filings; and, second, that of Branley, who ascribed the action to a breaking down or puncturing by minute sparks of the dielectric film (either gaseous or a metallic oxide), which he held must exist between opposing surfaces of the filings.

The result of the years of investigation which have followed the early work of these two pioneers proves that in a measure both were right. The Branley effect undoubtedly exists, and affords a satisfactory explanation of the self-decohering phenomena observed in the microphone type of auto-coherers. These insulating oxide or gaseous films inevitably form and cling to the surface of any metallic particles not enclosed in absolute vacuum, and where strictest care is not taken to prevent. They are, moreover, elastic, self-healing; and unless the electric impulses are of excessive violence, so that adjacent particles are actually welded firmly together, the original high resistance is automatically

restored upon cessation of the electric impulse. This is notably the case when the elements of the radio-conductor are of carbon, hardened steel, carbon-mercury, aluminum, etc., where the formation of this resisting film is easily accomplished, or where amid the minute roughnesses of the carbon surface the adhesion of a gaseous film is made more easy.

If, however, the coherer consists of filings of some soft metal of relative low fusing point—silver, gold, lead—the Lodge cohering effect through actual welding follows upon the Branley action; making the final fall of resistance far more marked, and necessitating a vigorous mechanical jar to break up the cohered filings and restore sensitiveness.

It is on account of this enormous change in conductivity of the filings-tube coherer that this form has been the standard used almost exclusively in the coherer systems of wireless telegraphy.

For the filings tube frequently shows a change from hundreds of thousands of ohms down to a few ohms under the influence of exceedingly weak electrical impulses.

This readily allows the use of a relay, operating a Morse inker and the tapping-back device; and in the old country, where the coherer systems have been chiefly developed, reading by sight has ever been deemed a necessity, especially in the navies, where, until recently, wireless telegraphy has enjoyed its most cordial reception.

The result of all this has been necessarily a system employing delicate relays, tapping-back adjuncts, complications of apparatus, requiring frequent and careful adjustments, a skill and delicacy on the part of the receiving operator seldom found outside of the physics laboratory, least of all upon a man-of-war, where the hands of Jack Tar, of the wig-wag and gundeck school, are all thumbs and of Cyclopic dimensions.

Despite many extravagant claims for high speeds of word transmission by coherer systems, I have yet to see proof of anything exceeding twelve to fifteen words the minute in genuine commercial working, while the actual every-day speed attained seldom exceeds half that amount.

For commercial applications of wireless telegraphy this pathetic speed limitation of itself renders the filings-tube systems to-day an impossibility; regardless of any other considerations, such as uncertainty of their action, ill-adaptability to electrical tuning, liability to interference (notably from atmospheric electricity), harmful effects from mechanical vibrations, etc., etc.

It has been stated by its early champions, and more recently by those prominently interested in *wire* telegraphs, that wireless telegraphy is destined to fill a place where existing methods of wire communication are impossible, such as from ship to ship and ship to shore. And their point was well taken; for, with the best tape-recording coherer systems developed to-day, after eight years of elaborate effort, no sane man would think of employing wireless telegraphy, with its six words and as many guesses per minute, its treacherous adjustments and its moody dispositions, where a wire system could possibly be used.

With the auto-coherer, or so-called microphonic contact, the case is better. Here, since no tapping-back is required, a relay is superfluous, although, to speak frankly, the changes of resistance in the auto-coherer are generally so slight and the *normal* resistance such a shifting quantity that no relay capable of operating reliably with the auto-coherer has been devised. A telephone, the most sensitive indicating instrument known, is invariably used to-day in place of the relay and inker; and, inasmuch as the auto-coherer is usually a quantitative instrument, possessed of no critical voltage, its combination with the telephone affords an extremely sensitive wave detector, the range of which is limited by the sensitiveness of the human ear.

With this arrangement one obtains a speed of word reception limited only by the ability of the operators to send dots and dashes with the transmitter spark, and to translate these into words. Consequently, in America one finds the alternating current of relatively high frequency and excellent regularity of action employed, with an ordinary Morse key obtaining a speed of twenty-five to thirty-five words per minute, instead of the antiquated induction

coil with its spluttering sticking hammer interrupter, or its messy, explosive mercury-brake and the pump-handle *Zeichengeber*, which is considered abroad as a fitting accompaniment to the coherer receiver, and is so well designed to hold down the impatient sender to a sloth sufficient for that form of receiver. As we frequently see in the daily press, the spark-coil coherer systems are excellently adapted to the trying requirements of a "chess game by wireless telegraphy!"

The auto- or microphonic coherer is, however, poorly adapted to the nice requirements of close syntony or electrical tuning. This is on account of its variable normal resistance and its normal capacity. Moreover, this device is liable to "close up" under the effects of severe static discharges, requiring readjustment by tapping, and rendering difficult its employment during time of severe atmospheric disturbances and lightning storms.

Furthermore, its inability to reliably operate by a relay, a bell for calling purposes often necessitates the addition of a filings-tube for that purpose.

I feel justified in saying while on this subject that the type of auto-coherer invented by Mr. Harry Shoemaker, until recently of this city, together with the special antenna which he employs therewith, is the most practical and satisfactory form which has come to my attention.

Having briefly reviewed the field of cohering indicators of electric waves, I wish now to call attention to an entirely distinct line of investigation leading up to forms of receivers which I believe may well be set in a class by themselves as regards sensitiveness, simplicity and general adaptability to most of the demands which can be made to-day in the field of wireless telegraphy. I refer to the electrolytic principle, one which has until recently attracted little investigation from experimenters generally, but which, notwithstanding, has to its credit performances which are rapidly compelling study and research in various sources here and abroad.

In 1898 the German, Neugschwender, performed the following experiment: The silver plating of a strip of mirror

glass was divided into two parts by a sharp razor cut, leaving a narrow gap between two silver edges, completely insulating the two sections. Each of the sections was now connected to the terminals of a dry battery, and a telephone and galvanometer inserted in series in the circuit.

No current was observed to pass until a film of moisture was deposited upon the slit, either by blowing the breath thereon or by placing a saturated sponge nearby or by placing a drop of water directly upon the slit. After a brief period the galvanometer began to show violent and irregular deflections. In the telephone a scratching, bubbling sound was heard, followed shortly by comparative quietness and a stable position of the galvanometer needle, indicating that the resistance of the gap in the silver mirror had been broken down until it measured but a few ohms.

If, now, electric waves were generated in the neighborhood, as from the spark of an induction coil, the galvanometer showed an increase of resistance in the circuit, while the listener in the telephone heard a purring sound, reproducing with singular fidelity the sound of the induction-coil spark.

Upon cessation of the electrical impulses the conductivity of the gap in the mirror instantly reasserted itself; the sound in the telephone ceased.

A year after Neugschwender discovered this strange action of the Hertzian waves, Aschkinass independently noted the same phenomena, the publication of which in *Wiedemann's Annalen* led the former to further pursue his researches, and to examine the action at the moist edges of the silver electrode under a powerful microscope. His observations thereon and my own investigations in 1899 coincide in all essentials, and clearly demonstrate that the phenomenon is one of electrolysis, due to the combined action of the Hertzian and local currents. They demonstrate, however, several features new to the generally accepted idea of electrolytic action; and open up lines of speculation and research of unusual interest to the physicist, and rife with suggestion.

The phenomenon noted above exist to a more prominent degree with tinfoil electrodes in place of silver, and these I shall now attempt to describe.

With the telephone to the ear and the eye at the microscope the action thus doubly observed affords in fact one of the most fascinating, most beautiful pastimes (as I may well term it) ever granted to the investigator in these fields.

When the local E.M.F. is first applied to the gap, minutest metallic particles, all but invisible even with a 1,000-power lens, are seen torn off from the anode, under the stress of the electric forces, apparently mechanical in action; and these dust-like particles, floating in the fluid, move across to the cathode, some rapidly, some slowly, by strange and grotesque pathways, or directly to their goal.

Tiny ferry-boats, each laden with its little electric charge, and unloading its invisible cargo at the opposite electrode, retrace their journeyings, or, caught by a cohesive force, build up little bridges, trees, with branches of quaint and crystalline patterns.

During this formative period (lasting perhaps for half a minute) the ear hears an irregular boiling sound, and the average deflection of the galvanometer indicates a gradual decrease of resistance, until one or more of these tin trees or tentacles has been built completely across the gap.

Then silence ensues until the current across this bridge is suddenly increased as by the Hertzian oscillations from an electric spark made in the neighborhood, or even from a source of so low frequency as the ordinary 60-cycle alternating current.

Instantly all is commotion and change among the tentacles, and especially where these join the cathode. Tiny bubbles of hydrogen gas appear, and enlarging suddenly break or burst apart the bridges, while the click in the telephone indicates the rupture of the current's path.

Yet they are persevering, these little pontoon ferrymen, and instantly re-form, locking hands and hastening from their sudden rout back to build new paths and chains. So the process continues, the local current re-establishing, the electric oscillations breaking up, its highways of passage, with furious bubblings and agitations—a veritable tempest in a microscopic tea-pot.

The hydrogen gas, having, of course, twice the volume of the oxygen, is most in evidence, and therefore the rupture of the tentacle occurs chiefly at its cathodic terminal. And where segregated branches of the tin trees are broken off, the bubbles of gas are generally noticed at the cathodes.

Moreover, the oxygen to a large extent enters into chemical combination with the tin, and after the slit has been used for some time a greyish deposit of stannous oxide may be scraped from the anode.

A peculiar feature of this phenomenon is the rapid disappearance of the gas bubbles. The hydrogen, and what oxygen does not combine with the tin, seems to be absorbed by the liquid; or the two, being nascent, may recombine to form water.

One fact must be borne in mind, that the fine tentacles (whose diameter, by the way, is of the order of some hundred-thousandths of an inch) do not come into actual metallic contact with the anode terminal. A film of electrolyte of almost molecular thickness must exist between the two, conducting normally by electrolytic ionization and conduction, yet easily decomposed and transformed by a sudden *increase* of current into an insulating gaseous film, the expansion of which still further increases the resistance of the gap.

The character of the electrolytic action when soft metals, such as tin, silver, lead, are used as anode, and when the distance to the cathode is decreased to the order of $\frac{1}{100}$-inch or less, is quite surprising. For example, the electro-motive forces needed for electro-deposition from anode to cathode are extremely small, nowhere approaching the critical E.M.F. of polarization of the electrolyte.

Moreover, distilled water, so-called chemically-pure glycerine, oils, etc., contain enough of impurities (such as acid traces) to enable them to act here like our ordinary electrolytic solution. I have in ten minutes plated a firm deposit of tin on a gold cathode, using distilled water only, and a potential difference not exceeding $\frac{1}{10}$ of a volt.

For the same reasons it is possible to decompose the water films interposed between branches of these tin trees

by a very minute difference of potential there-between. The result is that this electrolytic responder does not necessarily possess a "critical potential," as is common to a *coherer;* and it does not, therefore, cease to respond to electric impulses the potential of which is less than the E.M.F. of polarization of the electrolyte, as commonly understood.

This receiver is in fact a *current*-operated device, as distinguished from potentially-operated forms such as the coherer, as I have proved in a variety of ways.

Returning to the silver-mirror slit experiment of Neugschwender, my investigations soon showed me that the device was altogether unreliable as a practical wave-responding detector. In the slit form above described the tearing off of metal from the anode and the building up of conducting bridges and tentacles across the gap was found to continue until the whole gap became clogged with an agglomeration of crystalline formations, affording so many short-circuiting paths in parallel that very soon the auto-cohering could be obtained only in response to powerful sparks.

Again, an accumulation of hydrogen gas may obtain, completely preventing the reforming of a water film between tentacles and electrodes or between sections of the tentacles. There results thereupon the regular coherer arrangement, and at the first electric impulse permanent welding of the chain ensues, so that the device becomes inoperative until cleaned out or readjusted.

Systematic and painstaking experiments extending over two years were required before the electrolytic "responder," as I have termed it, assumed a commercial form.

As described in U. S. Patent 716,000, a viscous supporting medium, such as glycerine, heavy oil, or one mixed with an absorbent such as lycopodium powder, may be inserted between the electrodes to prevent the agglomeration of conducting paths, to confine the action to a few only and to prevent the permanent formation of gas among the tentacles.

In addition a depolarizer was added to chemically dispose of the hydrogen bubbles. This last factor has proved of greatest value, rendering the responder of extreme sensitiveness and reliability.

Other electrolytes, such as dilute acids, alkalies, alcohols, ammonia, etc., were early tried, but I found generally that such lead to a too violent disintegration of the metals in the responder.

It has frequently been asserted that the Marconi coherer when connected directly between the foot of an upright aerial conductor, of about 60 meters height, and the earth, failed to respond to impulses from a typical 12-inch induction-coil transmitter set at distances exceeding twenty miles. For longer distances it was necessary to insert a "jigger" or transformer, by means of which the potential difference across the terminals of the coherer could be stepped up to that required by the so-called "critical potential" of the coherer.

A carbon microphone auto-coherer is a current-operated device. It can, therefore, be inserted without a step-up transformer directly at the foot of the aerial wire, and shows no such failure to respond for the distances above mentioned.

If high-frequency electric oscillations from a distant source be impressed upon a vertical conductor grounded at its lower end, current oscillations will be induced in the surface of the conductor, traversing it from top to bottom. At the upper extremity the electro-static components of the oscillations will be reflected without change of sign, and at the base reflected *with* change of sign. The exact converse holds for the electro-magnetic or current components of the oscillation. The result is a loop of electro-static force at the upper end of the wire, and a current loop at its base. A current-operated device, therefore, will respond best when inserted in the base of the aerial at a point where the *coherer* is at its greatest disadvantage.

The extreme distances from which messages have been received on the electrolytic responder of the types just described, as compared to records with the coherer under similar conditions, afford a practical proof that it is a current-operated device, in addition to the consideration of the electrolytic principles involved in its action.

As an interesting instance of the work done by the re-

sponder under such conditions, I may cite the following aerogram received at the Coney Island Station of the de Forest Company, March 14, 1903, and addressed to President Schurman, of Cornell University. The message was sent by Charles De Garnio, professor of pedagogy in that institution, from on board the S. S. "Coamo," bound to Porto Rico, using a 10-inch coil and an antenna of only 90 feet, the distance being 110 miles: "Greetings from Old Ocean, who no longer sunders friends. Courtesy de Forest wireless telegraph system." Signed.

I call your attention now to a remarkable fact which I have discovered in connection with the electrolytic action of Hertzian waves.

The sensitive cell, as above described, shows nothing of a counter electro-motive force of polarization, although the electrodes may be of a great variety of shape and materials.

The locally applied electro-motive force may range from a few millivolts to 3 volts or more, but always with a proportionate increase of indicated current-flow.

If, however, the electrodes be slowly separated from one another, with one or more of the minute tentacles clinging thereto, a counter electro-motive force of polarization may be observed when the distance between the nearest electrodes exceeds a certain small limit. This counter E.M.F. exists whether the electrodes be of like or unlike material or shape.

Now, upon the first application of the local battery to the terminals of this cell, a temporary flow of current is observed, the resistance of the cell being at first slight, especially if a dilute alkali or acid form the electrolyte. Immediately thereafter, however, the current flow falls almost to nothing; the counter E.M.F. of the cell asserts itself. This, as is well known to the science of electro-chemistry, is due to the formation of a layer of gas insulating the faces of the electrodes. This requires that, unless some depolarizing means be added, the local applied electro-motive force must be raised above the opposing electro-motive force of the cell; that is to say, above the critical voltage required for the decomposition of the electrolyte.

This counter E.M.F. of the cell exists whether the fine tentacles be attached to the anode or cathode.

Now, when the cell is placed in the path of the high-frequency electrical oscillations the effect is found to be a temporary, more or less complete, annulment of the counter electro-motive force of polarization. This effect is scarcely noticeable when the tentacles are made the cathode; but when made the anode, so that oxygen is the gas surrounding and insulating the fine tentacles, the effect of the Hertzian oscillation is to decrease to a marked degree the apparent resistance of the cell.

The sensitiveness of the electrolytic cell to this second action of the Hertzian oscillations is nearly inversely proportional to the exposed area of the anode. It can be obtained even for such coarse anodes as are furnished by a 1 millimeter platinum wire; but the diameter of these is 100 times that of the fine tentacles or trees previously described.

Last year a German experimenter, Schloemilch, reported the independent discovery of this same effect in what he called "polarization cells." Anodes having diameters sufficiently small to give great sensitiveness to the responder are now obtained by mechanical means, using the Wallaston wire having gold or platinum core and a silver sheath; wherewith, after drawing the whole to a fineness of 2 or 3 millimeters, the silver sheath is dissolved in concentrated acid in the manner long known to the arts. The order of diameter thus obtained is comparable to that of the metallic trees built up by electrolytic deposit; but the wire anodes are more stable and better suited to the work in this second type of the electrolytic responder.

To recapitulate these points:

Electrolytic effects of the Hertzian oscillations are available in a practical detector whenever extremely fine tentacles or wires are used for one of the electrodes:

(1) When such tentacle is brought into close proximity of the other electrode, preferably the anode. The normal resistance of the cell then becomes very small, generally a few hundred ohms. The cell offers no counter E.M.F. of polarization. A minute film of liquid intervenes, conduct-

ing by ionization. The passage of the Hertzian oscillation will now decompose this film, insulating the fine electrode, and causing a temporary and marked decrease in the local current flow. This is a current-operated device, and is extremely sensitive when inserted as a potential node, directly at the base of the receiving antenna.

(2) When the anodic tentacle is withdrawn from proximity with the other electrode, of whatever shape or material. The normal apparent resistance of the cell now becomes very great, 30,000 or 50,000 ohms, due to the counter E.M.F. of polarization.

A minute film of oxygen gas normally envelopes the submerged surface of the fine cathode tentacle, practically insulating it. The passage of the Hertzian oscillation will now cause a temporary dissipation of this gas, apparently into the liquid, causing a marked increase in the local current flow. This is a potential-operated device, and is best located where can exist potential loops of opposite sign at its two electrodes.

One investigator, prominent for his inventions in the wireless field, maintains that the phenomenon observed in this second form of the electrolytic responder is a *heat* effect. I have been unable, however, to find a single fact warranting such a view.

First of all, the fact that the device is a valve-effect, not indifferent to the direction of applied local potential, but practically inoperative if the tentacle be made negative, shows that the results obtained are not chiefly C^2R effects, as would be required were the action a heat phenomenon due to the amount of current flowing. Second, that it is a potential-operated and not a current-operated device, possessing a capacity, and normally insulating the fine anode. Third, that its action is sensibly unaffected by extremes of temperature, high or low. Many other considerations, based upon theoretical calculations as well as practical experiment, upon which I cannot dwell at this time, point to the correctness of the explanation of the action involved, based entirely upon electrolytic phenomena.

The electrolytic responders which I have described seem

to possess in the highest degree the qualities necessary to place the art of aerography on a basis to compete with existing telegraphic service, by land as well as by sea. They are extraordinarily sensitive, regular in response, strictly quantitative, automatic in action, having approximately constant normal factors as regards resistance and capacity, allowing thus a speed of word-transmission limited only by the ability of operators to send and receive. By such means the problems of electrical tuning, or syntony, are enormously simplified; for heretofore the erratic nature of the coherer has rendered it impossible to closely regulate the constants of the tuned electrical circuits in which they are placed; thus making syntonization by their employ at best crude and uncertain.

In regularity of action the responder is strictly comparable with the Rutherford magnetic detector as developed by Wilson, Shoemaker, Marconi and Ewing, while as regards relative sensitiveness there is to-day no comparison between that of the magnetic detector and the electrolytic receiver. Moreover, the device is practically indestructible, while its syntonizing qualities enable me to so cut out foreign signals and electric disturbances as to render wireless communication by this means practically immune from interruption.

In corroboration of these statements allow me to call attention to the service which the American De Forest Company has now established between Cleveland and Buffalo. The distance here is 180 miles, extending, as the two stations are located, almost entirely overland. During the recent severe weather, when this land was frozen to a depth of several feet, and Lake Erie a mass of ice extending from the shore for miles (conditions which afford the greatest difficulties for aerographic transmission), the daily exchange of messages at high rates of speed has been continuous. The loudness and clearness of the signals are most surprising, originating, one might suppose, from some station less than 30 miles distant. Tuning here is so close that the addition or subtraction of 6 to 8 inches of wire in the syntonizing coils cuts out the signals altogether and enables the operator to dispose entirely of atmospheric disturbances

arising from severe lightning storms in the close neighborhood of the stations.

During a recent test to Lockport, 36 miles overland from the Buffalo station, messages were received on two small wires extending to the roof of a building but 85 feet above the earth, with the utmost clearness and accuracy.

Again, the recent excellent record which the United States Signal Corps has made between Fort Schuyler and Fort Wright, 98 miles apart, concerning which so much has recently appeared in the daily press, was made with receivers, tuning devices and oscillator sets purchased from the de Forest Companies. As a result of this work, following upon the failure of several coherer systems to cover the distance, the apparatus is to be installed next summer in Alaska between Nome and St. Michaels, over a range which the Signal Corps has sought in vain for several years to cover.*

The exact nature of the electro-magnetic waves by which wireless signals are transmitted has afforded field for a great amount of speculation and theory among scientists and laymen. Considerable interest has attached to the discussion of this subject, which has recently been running in the columns of the *Electrical World and Engineer.*

Unfortunately the classic work in exploration of the field of force and the nature of propagation from the dumb-bell oscillator, by which Professor Hertz immortalized his name, is not entirely applicable to the case; but the analogy is very close. When the lower half of the Hertz oscillator is substituted for a connection of that side of the spark-gap to a conducting or semi-conducting medium of unlimited extent (such as sea water or the earth's surface), the laws of electrical images do not strictly hold.

This was, however, the view taken by Abraham in his mathematical investigation of the subject; by Blondel, at least until recently, and others.

Mr. J. E. Taylor, engineer of the British General Post

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* Since this paper was written these Alaskan stations have been opened. Capt. Wildman reports the system as giving complete satisfaction.

Office, and a zealous pioneer in wireless work, was, I believe, first to apply in a clear and lucid manner the theory and diagrams of Hertz to the case of the grounded oscillator. Taylor pointed out that we had in practice the sliding wave, following in general the shape worked out by Hertz; but with the feet of the lines of force which form the polarized wave-front gliding over the surface of the earth or sea, following the contour of hill and dale; and scaling such obstacles as do not absorb portions of the wave energy and cast thereby more or less serious shadows.

The Hertzian field of force does not call for approximately spherical radiation of energy, as seems to be taken for granted by some; and my own experience goes to show that the falling off in the strength of received energy does not follow anything like the law of the inverse squares of the distance, as this assumption would require.

The electrolytic responder is quite exactly a quantitative instrument, and with it I find, at distances far from the course of oscillations, a decrease in strength of received signals approximately proportional to the first power of the distance.

One fact is certain, that the propagation is not by hemispherical waves. One searches in vain the writings of Hertz for anything suggesting such a theory there. Hertz points out that even with the free polarized wave in space the force diminishes continuously with the inverse distance; at first rapidly, as the inverse cube, but later slowly, as the inverse of the distance itself. So at great distances will the effect of oscillation be marked only in the equatorial plane; that is, in our case, in the region nearest the earth's surface. On the other hand, the electric force in the direction of the axis of the oscillator, or vertically above the radiating antenna, falls off very rapidly, at first as the cube, later as the square of the distance.

Thus, at great distances, an appreciable effect from the Hertzian waves sliding over the earth's surface need not be expected at distances far above the surface. This does not require an hypothesis of the reflecting power of a highly-conducting stratum of rarified air, at an elevation of several

miles, as has been ingeniously suggested to account for the departure of the phenomena from the law of the inverse squares.

Possibly such strata may influence the radiation outwardly into space to some extent. But an exact knowledge of the actual field of force, both on the earth's surface and in the ether surrounding the transmitting station, can only be had by a thorough exploration with detecting oscillators, and under conditions such as obtain in practical, long-distance working; an exploration such as Hertz conducted in the laboratory at Karlsruhe, in that masterly way which so characterized his work.

Such work must obviously be undertaken in a captive balloon or air-ship, and will be attended with obvious and costly difficulties. A beginning was made several years ago by Captain Ferrie, of the French Artillery, but has never been pursued.

With the unequalled facilities offered this summer at the World's Exposition at St. Louis, both as regards a transmitting station of unusual power, or others of lesser range, and as regards vehicles for aerial navigation, it is to be earnestly hoped that more light may then be thrown upon this subject, so full of academic and practical interest.

The results of years of patient experiment, careful research, accompanied often with disheartening failures, on the part of the investigators in the wireless field, frequently fail to meet the full expectations of the public. The difficulties to be overcome can of necessity not be realized by those unacquainted with the exact details of development. Such, alas, has been the history of all invention, all progress. It is gratifying to know that the fundamental obstacles at least are in so large a measure overcome, that development in this, the field possessing perhaps the most popular interest exhibited in any age towards any invention, any discovery, has yet been steady, although at many times slow and faltering.

The difficulties remaining are manifold and great. The development of the past is an earnest of the greater things

which are so surely in store for this new and humanitarian art.

DISCUSSION.

PROF. GEO. A. HOADLEY:—I understand that the Hertzian waves decrease the resistance of the coherer in the Marconi system to such an extent that it is possible to use a local circuit and Morse instrument as a receiver. In this system, since the Hertzian waves increase the resistance of the electrolyte, such an instrument cannot be employed. What is to be used, a telephone receiver?

DR. DE FOREST:—In reading we always employ the telephone with the electrolytic receiver. This combination is the simplest and most sensitive possible and requires no attention or adjustment from the operator. The result is a speed and accuracy of reading impossible by relay; and the trained ear of the operator enables him to instinctively discard false or interfering signals, atmospheric or otherwise, and to attend exclusively to the signals having the distinctive sound of his transmitter spark. We can thus, with two telephones in series, and two operators, read two distinct messages without any other tuning.

A relay can, however, be used with the electrolytic receiver. On account of its sensitiveness and regularity of normal, I use this merely to ring a calling signal. But the records which my system has to its credit, often in competition with tape-register systems, justify, I think, this policy of simplifying the apparatus to the greatest possible extent.

MR. E. A. SCOTT:—In consideration of the fact that the earth, as a mass, is a conductor without resistance, would it not be practicable to make a ground connection with the two stations of sufficiently low resistance to use the earth as a current chute as the water is now used?

DR. DE FOREST:—While the conductivity of the earth as a mass may be considered as infinite, yet only that of the surface lying in the zone of influence from any transmitter station can enter into the question. This conductivity of course varies with the locality, and the quality and dampness of the soil intervening between the two stations. If this chanced to be especially better than the conductivity

of the surrounding country we would find the conducting strip acting in a measure as a "wave-chute," leading a greater portion of the wave energy in that direction than was propagated in other directions of the compass.

Such a condition would be offered in an arid country where the conducting surface was confined largely to the neighborhood of a river or its valley, lying in the line between the two aerograph stations.

A system of railroad tracks would act in this manner, and if both transmitter and receiver instruments were connected to these tracks transmission along the line would be especially good.

MR. CARL HERING:—Would not the presence of large quantities of telegraph wires, or large metal masses, interfere with transmission of your messages?

Would not the submarine cables play a part in transatlantic wireless?

DR. DE FOREST:—A mass of horizontally extending telegraph wires would have little effect on the transmission of "wireless" signals if the wires extended at right angles to the direction of propagation.

The lines of static displacement in the wave are vertical, and hence it is only the vertical components in the telegraph wires which would cause a reflection or absorption of the wave energy.

In the case, however, of large vertical masses of metal, such as elevators, gas-reservoirs, steel-framed buildings, etc., a very considerable shadow effect of the waves is observed.

This is in accordance with the experiments of Hertz and Lodge on the polarized properties of the Hertzian waves.

On the other hand, if the line of telegraph wires extend in the direction of propagation, they afford a conducting path for the waves, and we find the propagation actually aided, with a tendency to confine or concentrate the energy propagated along that line.

The same thing is noticed in the laboratory, where a simple wire lying along the floor, and not connected either to transmitter or receiver, will greatly aid the transmission, if it lie in the proper directions.

I have noticed the same thing to a marked degree at one of my stations, where a single telephone wire leading into stations extended for several miles in a straight line towards the transmitting station.

It was possible to obtain the messages by connecting the receiver between this wire and earth fully as well as from the 180 feet antenna, although the distance to the transmitter was some 15 miles.

If this wire were extended at right angles to the line of propagation, we would expect no such action from it.

DR. E. GOLDSMITH asked the lecturer whether the earth or the water was not necessary for the transmission of aerial messages; and also whether the high poles built into the ground did not assist to help the transmission; how high have the poles to be in order to send messages across the Atlantic Ocean? It seemed to him that iron ships floating on the water helped in a measure the transmission of the waves.

DR. DE FOREST:—The conductivity of the earth or water surfaces over which the sliding waves are propagated enters very greatly into the phenomena. Therefore is it that we are enabled to operate over greater distances by sea than by land with a given quantity of transmitted energy, other conditions being the same. Moreover, overland the vertical wave-fronts are more or less cut into by obstacles which they there meet—forests, precipitous hill-sides, buildings, metal structures, etc. Every such obstacle absorbs or reflects a greater or less amount of the energy of the waves, depending on the dimensions, conductivity and shape of the obstruction.

It is necessary to extend the vertical transmitting and receiving wires to a certain height, roughly depending upon the distances to be covered. The commonly-accepted law is that with a parity of other conditions, the distances attainable are proportionate to the square of the height of the aerial conductors. But to-day a great number of other conditions and arrangements modify this rule.

Signals have been sent across the Atlantic using antenna 225 feet in the vertical, although the length of these

wires is much greater. That height is about the limit to be obtained in practice.

Obviously it is not necessary that the tops of the two masts, or towers, should lie in a line not cut by the curvature of the earth, for reasons already explained.

The distances attainable are nearly proportionate to the amount of energy transmitted, although the length of wave used plays a considerable part. Roughly speaking, the greater the energy the longer the period of oscillation of the radiator circuit, and the greater must be the length and the capacity of the antenna to be in resonance with such periods.

No better grounding conditions can be afforded than those found on an iron-hull vessel floating in sea water. Hence the long distances which are often attained under such circumstances.

ELECTRICAL TRANSMISSION OF PICTURES AND SCRIPT.

A correspondent of (London) *Nature* refers as follows to a method and apparatus for this purpose lately described by Dr. Arthur Korn:

The problem of distant electrical vision is one to which much speculation and experimenting have been devoted. Before this problem can be attempted with any hope of success, however, the preliminary one of the electrical transmission of photographs over a distance has to be solved. This problem, it may be stated at once, has been mastered, and it is now possible to transmit photographs in this manner, and successful results have been obtained over telegraph and telephone lines 800 kilometers long.

It does not need much consideration to see how important such a process would be for journalistic and police work if it could be industrially exploited, and it were possible simply to hand a sketch or photograph in at the telegraph office and send the same as one now sends an ordinary telegram. The evening papers would be able then to publish photographs taken at the seat of war in Korea on the same day. Unfortunately, with the apparatus at present to be had, the time taken to transmit a half-plate photograph is half an hour. The cost of the use of a telegraph line of any length for half an hour would be, it is needless to point out, prohibitive. The lessening of the required time of transmission is, however, simply a matter of further development, and no good reason can be seen why in a few years' time the process should not be an adjunct to every existing telegraph line.

The method shortly consists of the following: A ray of light is made to pass systematically all over the transparent film to be transmitted. After passing through the film it impinges upon a selenium cell the resistance of which varies proportionately to the amount of light which passes through the pho-

tograph. These varying currents pass through the line and are received in a moving coil galvanometer the pointer of which, in moving, inserts or takes out resistance in a high tension circuit, according as the current flowing in the moving coil changes. In the high tension circuit a small vacuum tube is connected, and it follows that the illumination of this tube is proportional to the light passing through the plate at the transmitting end of the line. This vacuum tube now passes over the sensitized photographic paper in synchronism with the ray of light over the transmitted plate, and thus a reproduction of the same is obtained. The transmitted film and sensitized paper are each wrapped on a glass cylinder. These cylinders are rotated by motors, and synchronized once each revolution. Only one wire is needed for the transmission, with, of course, an earth return.

In the case of the transmission of handwriting and half-tone illustrations, the same are got up on metal foil with electrical non conducting ink. A conducting point then travels over the metallic foil, and closes and opens the sending circuit according as it is traveling on a marked or an unmarked place. The receiver used by the author is a modification of that described above, the essential point being the use of the vacuum tube fed with the Tesla currents. The speed reached is 500 written words per hour. For a half-tone illustration a strip ½ centimeter wide and 10 centimeters long can be sent in 100 seconds.

It would seem that there is not very much practical value in the transmission of handwriting; the type-printing telegraph of to-day fulfils all ordinary requirements, and it would be only very seldom that a transmission of handwriting would be required. It is to be hoped, however, that this electrical "distant photography" will make rapid progress.

REGISTERING COMPASS.

A compass which automatically registers minute by minute has been patented by M. Heit, a French inventor. The compass card is fixed on a steel pivot, which rests on a fixed agate, instead of having at its center an agate resting on a fixed steel point. The fixed agate is immersed in a drop of mercury, which serves as a conductor for the electric current that causes the movements of registering. By the use of this instrument it is claimed that a ship's officers have a complete record of a voyage.

FERRO-CONCRETE RAILWAY TIES.

Some interesting tests are being made on the railroad between Voiron and Saint Béron, in France, with ferro-concrete in lieu of wooden railroad ties, to ascertain the comparative initial and maintenance cost, efficiency and durability of these two systems. This track is 3 feet 3 inches gauge, and the ties are 3·9 feet long by 7 inches wide and 5½ inches deep. They weigh 23 pounds each, and cost approximately 50 cents each. The concrete used is composed in the proportion of 33 kilograms of cement to 40 liters of sand, and the reinforcement of steel bars weighs 8·4 kilograms per tie. Under the most unfavorable conditions, it is even considered that the first cost of the ferro-concrete ties will not exceed that of good oak ties more than in the proportion of 5 to 3, while it will be four or five times as durable.—*Scientific American.*

ELECTRICAL SECTION.

Stated Meeting, held Thursday, April 14, 1904.

Telpherage.*

BY C. J. MESSER,
United Telpherage Company, New York.

The nineteenth century passed into history with a record of such stupendous development from the chimerical to the practical that, even considering all other progress since the world's beginning, it may, with reason, be designated the age of innovation. At its ingress Mynheer Peter Van Stuyvessant "coached it" from Philadelphia to New York, occupying a couple of days in the trip. To-day, his grandson, Peter 3d, wires his agent to meet him at the Waldorf-Astoria at 2 P.M., catches the Washington Express, goes over in two hours, hustles around and borrows a million at 3 per cent., informs his partner in Philadelphia of the transaction by wire—the entire twentieth century accomplishment occupying about five hours.

This is a swift age. In a hundred years the commodity which has experienced the greater advance in price is time. Peter's great-grandfather stopped *en route* a stage occasionally to see his cronies, for in those days one might catch a few odd naps with both eyes without the danger of losing financial or social prestige; but when Peter 3d sleeps he has some one to watch the ticker, for wonderful transformations now occur in a single night.

Time began to advance in price, and all other commodities to cheapen, with the conception of an artificial-power application to mechanism. The ancients, having a plethora of slave labor, simply touched the environment of the science of mechanical dynamics when they invented the water-wheel. It took about 6,000 years for man to learn that fire and water made steam. Before that discovery world-devel-

* The paper was freely illustrated with lantern photographs, a number of which are herewith reproduced.

opment had been carried on through conquest of the weaker by the stronger; but with the discovery, dynamics became the most powerful factor for civilization and progress. In the electric dynamo, the last child of dynamics, however, it would seem that the efforts of all previous energy-dispensing mediums were to be outdistanced.

Time being the most expensive commodity, and electricity the most effective agent in reducing happenings to a due appreciation of that fact, prudent statisticians of producing properties are naturally interested in any device which adds an increased efficiency to their joint action. One of the most attractive of such exhibits now before the public is the conveying system—telpherage.

Possibly there is as little knowledge concerning telpherage in the rank and file of workers in electricity as there is of radium among laymen. Telpherage is a comparatively new science, and the world is large, and to these two facts the busy delver among volts, amperes and ohms may place the blame for his seeming disinterestedness.

Possibly, again, another decade will not have passed before even the student in electrical matters will be directed to telpherage for a standard in computing maximum force effect in electrical propulsion, for it is a recognized fact among those experts who have examined into the subject that between no other species of mechanics, and motive power, is there such congeniality.

Telpherage means far-carrying, and the word was coined very early in the career of this subtlest of all moving forces —electricity. Some of the first experiments in electric propulsion were worked out on the identical principle of construction as is now so successfully employed in the scheme under discussion.

At the beginning it was decided by eminent authority that in an aerial system of transportation would be found the least obstruction for propulsion by electricity. Prof. Fleeming Jenkin used an elevated structure with suspended load to demonstrate his safety block system, dividing his line into live and dead sections, and making it possible that a train entering one section should cut out that section just

left. By the discontinuance of motive force on that section, possibility of accident from collisions was reduced to the minimum. It was Professor Jenkin who first used the word telpherage as a distinctive name for electric traction on these lines.

The first experiments in electric propulsion were almost wholly confined to freight transportation, but there was to be a wide divergence from this plan before electricity

The old and the new way.

became the docile agent of man's will. A condition existed which offered to the inventor who would improve on the horse railway system of passenger carrying, speedy fame and fortune. When all requirements had been met, capital seemed to lose its head in an effort to get mixed up in the matter, until now we learn from railway commissioners'

reports that the electric street railroad proposition is considerably overdone.

Twenty-five years ago experiments for passenger traffic on this same principle as is now employed in telpherage were carried to a high stage of perfection, but the time was not ripe for success. Valuable street franchises, which had cost nothing, must be utilized.

It may appear inconsistent, but the public domain is of less value than manufacturing property in private hands. In the illustration here shown, the proprietors of the mill could not afford to give space to passageways for teams, and finding something that would allow of a removal of that evil, they later found that they had also been paying too much for conveying.

Telpherage comes under the head of "intermittent control" type of electric propulsion, consequently is best adapted to the action of direct current. In the mill or manufactory, the incandescent plant is utilized, and the cost of operation usually puzzles the mechanical engineer who has been accustomed to figure a 40 per cent. efficiency loss in friction. With a machine and an assistant, a telpherman can convey 250 tons per day over a distance of 1,000 feet. The conveying differs from the general meaning, as attributed to that word, when it is considered that the telpherman takes entire charge of the loading, the carrying and the unloading. How many men and horses would be required in the lifting, conveying and depositing of 250 tons in ten hours, and when all is reckoned, score still an advantage for telpherage, as it occupies space hitherto considered useless in the plant. Snow, ice, or frost thrown surface cannot make more difficult the transportation problem, for telpherage runs in the air. The track is usually at least twenty feet from the ground and the material to be transported is suspended beneath, the supporting arrangement presenting no greater obstruction than would be encountered in an overhead bridge. The telpherman can reverse his machine at will, and when out of commission for even an hour, the plant becomes a non-consumer except in interest charges.

In a general sense, demand for local transportation facilities has never exceeded the supply. Men are plentiful and they can move weights. Horses are especially designed for that purpose, and, following that thought, it is wonderful to consider how far they have been displaced from that for which they were designed, by man's ingenuity, and for the benefit of humanity. It has ever been the rule that a sufficiency in any article hinders development along that line, but what I would now show is that the complexion of the argument changes when an effect on manufacturing economics is considered.

The horse is not an expensive article about manufacturing plants, even though he is idle one-half the time out of a working day, and though his energy is in no way comparable with that of electricity when he is actually at work. It is the preparation of the load for the horse's services, which runs up transportation cost. Even though the price of the horse should be pitted against that of the telpher, advantage would be in favor of the latter on account of the greatly accelerated speed of movement; but I believe it can be easily shown you that there is absolutely no comparison between the values of the two mediums of transportation.

Recently I stood forty minutes to observe the movement of five cases of finished cloth from a packing-room to a storehouse. In the operation six men and two horses were employed. Three men ended the cases upon a truck and wheeled them to the elevator; then a drop was made to the ground floor. The combined effort of five men was used in getting the cases from the elevator to the platform of a dray. A driver handled the ribbons while the load was moving the 600 feet to the storehouse, the five lumpers being part of the load; then, at the other end of the line, the six men were required in the unloading of the dray and the conveying to another elevator, which in two loads took the material to the second story of the storehouse, where men, not accounted for in the illustration, loaded it again and wheeled it to its resting-place.

It was a rather singular analogy that inside the buildings of the various departments of the manufacturing plant, ex-

pensive machinery was being driven to its utmost capacity that the cost of production should be reduced, while here was at least 240 minutes of manual and animal labor expended in a simple problem of conveying. The cost of this operation, not including time of horse, interest on horse, wagon, harness, etc., was at least 60 cents.

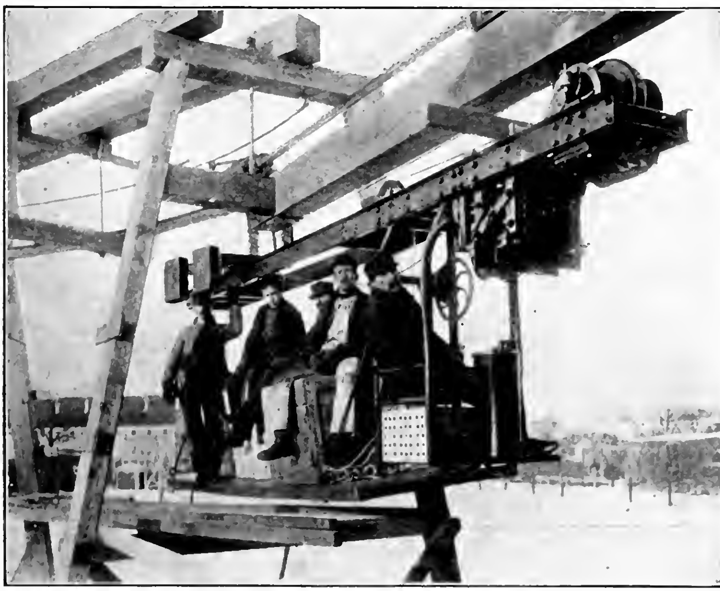
I will tell you what that 240 minutes was worth to the manager of that manufacturing plant and to his stockhold-

The long detour in crossing between the mill and storehouse is avoided.

ers, if an equally careful surveillance had been exercised in indoor and out-of-door economics.

Fifty cases of the same weight could have been transported between the same discharging and receiving points, the energy employed being a telpher outfit, a telpherman and a helper, and the entire cost, reckoning interest on plant, depreciation, power and wages, would be less than $1. I would like some mathematician to figure the loss in capital energy by reason of the cited carelessness on the transportation side of production.

It is no exaggeration to claim that there is not a manufacturing plant in operation which could not materially reduce cost of production if the usual carefulness of detail was extended to the transportation end. It may be, however, no fault of the manager that this is so. A manager is busy enough in caring for phases of the business which are continually demanding his attention, and he may be excused if the knowledge has not come to him that in the past five years an entirely new significance has been given



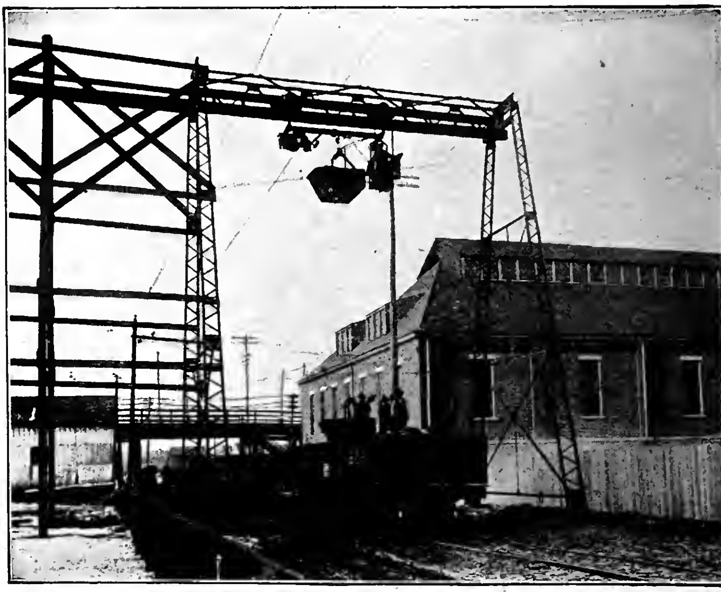
The load, with the five men, lifted 50 feet and conveyed 1,000 feet, showing massiveness of construction of the conveying and hoisting machinery, method of electrical control and brake wheel.

to the term, local transportation, by the strides of progress made in the science of telpherage.

If you have ever been in a large dressed-meat establishment, you have seen one man push a huge carcass of 1,200 pounds with one hand. In no other method of traction could that same task be performed; still there are disadvantages in that system. The stress is so applied as to produce unnatural resultants; consequently, an abnormal

leverage and friction, when comparing the weight movement with that as applied in operating telpherage.

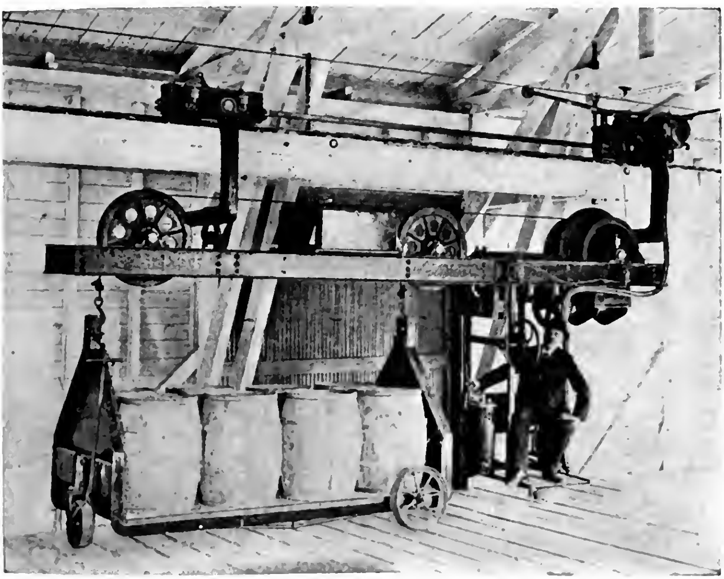
In telpherage the motive energy is directly applied to the frictional points. The bearings of telpher, trailer and hoist are encased in oil or grease, and the material weight is divided, the load supporting downcomes being centered in accordance with the requirements of the problem. We thus



Full bucket starting up the grade. Empty bucket being filled. Light steel trestle, long span. The track is T-rail upon stringer. The coal can be taken either from pits between or at the side of the tracks, either by the self-dumping buckets, as shown in the photograph, or by means of the clam-shell buckets.

see that in telpherage we have a system in which is discounted the advantages peculiar to the hitherto supposed most efficient method of weight movement. Out of doors the telpher track may be constructed of solid steel or of steel cable, the latter being invariably used in long spans over canals, river gulleys, railway tracks, or when the line is to run at an altitude of 50 to 100 feet. Under such latter conditions the running cable track is supported between posts by

C-shaped wrought-iron hangers, which have an upper grasp on a stout suspension cable and a lower clutch on a 3-foot beveled shield into which the running cable is sunk. The tightening of the suspension cable not only prevents excessive sagging of the running cable under a load, but maintains it at a slight elevation, so that when the telpher crosses the shields, the track is level. In all cable installations the spans, which are nominally 50 feet, have this simple



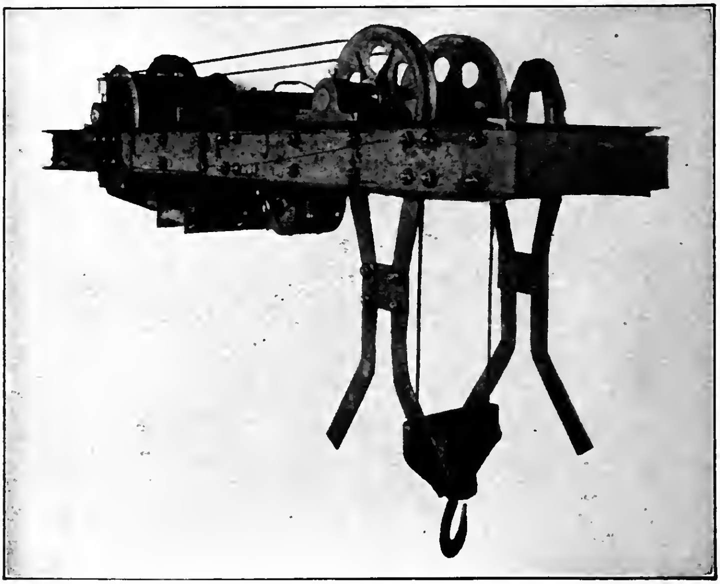
Track adjustable so as to be easily leveled. Suspended from the cross timbers. One man does the work of moving tons up any incline to a vertical by the hoist, any horizontal distance or up-grades by the telpher, by merely turning the electric switch.

suspension, but over rivers, double, triple and even quadruple suspensions are required, the necessary suspension dip being secured from high structural steel towers at either side of the depression.

The telpher, or locomotive, is of the simplest construction. In concentrated conveying, or where the load is suspended from one point, as in coal carrying, a follow wheel is affixed to the telpher frame to prevent excessive pendent acuteness,

while for distributed loads a two-wheeled trailer is attached to the telpher by a connecing rod. Invariably the trailer is used where a telpherman operates the machine. The trolley wire is above the track, but inside buildings this wire may run alongside, inclosed in a conduit, thus absolutely insuring safety against conflagration. The track for inside work is solid steel supported every 15 to 25 feet.

Here we have a machine showing a telpher with its



Details of one of the more massive hoists with exceptionally large drums and sheaves for high speed.

trolley poles, the trailer, and a two-sheave hoist. The controlling devices are directly at the telpherman's hand, the whole consisting of apparatus for enormous freight-bearing as simple to control as is a street car—in fact, more simple, for the telpherman is taught his work in three days without trouble. The primary cause for exceptional compatibility between machine and power rests in the fact that there is less frictional resistance in the former than has before ever been attained in a heavy-weight bearing vehicle.

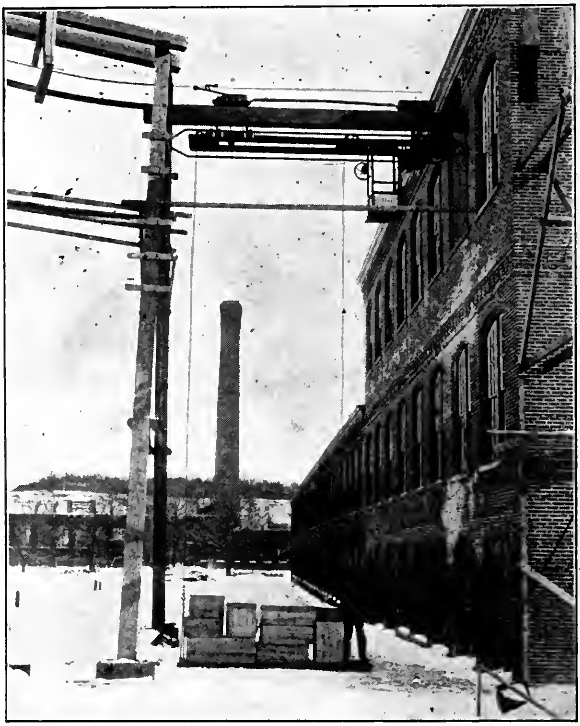
The hoist used in telpherage is a beautiful piece of machinery. It is composed of a double gear, a worm and drum and in its position on the telpher frame comes as near to being a direct-connected appliance as anything on the market, consequently the percentage of efficiency which gets to the load is remarkably high.

A gas engine, consuming but a few cents' worth of fuel per hour, and a direct-connected generator represent the minimum of power cost up to a 12-horse power requirement, and such an engine and generator will considerably more than suffice for all but extraordinary installations of telpherage. In those methods of conveying where each unit or combination of units to be moved is dependent on the stationary engine and drum, the producing qualities of the conveyor bear no sort of economic relationship with the productive force. The stationary machinery must be employed unintermittently to be ready at any time to take on a load. In telpherage this principle does not apply. As the several conveying units are independent, that is, as each conveying unit is under its own power, its effort of power consumption is relieved from the line immediately it becomes non productive. The computation of actual horsepower hours, therefore, as applied to telpherage is a subject which even the electrical engineer may study with profit when considering freight handling.

Telpherage is of three types—non-automatic, semi-automatic and automatic. In the former the telpherman rides on his machine and controls its every movement. Where his several distributing points are all over a plant, and it would be expensive to maintain a tender to care for his receipts and deliveries at each point served, the telpherman may be his own loader and unloader, as well as hoister, conveyor and depositor.

This very interesting telpherage installation has been made in a cotton plant in New England, and transports cases of goods between two buildings 1,200 feet apart. A pendent attachment permits the telpherman to lower himself 40 feet; consequently, with trap-doors in floors he may personally attend to all loading and unloading on the differ-

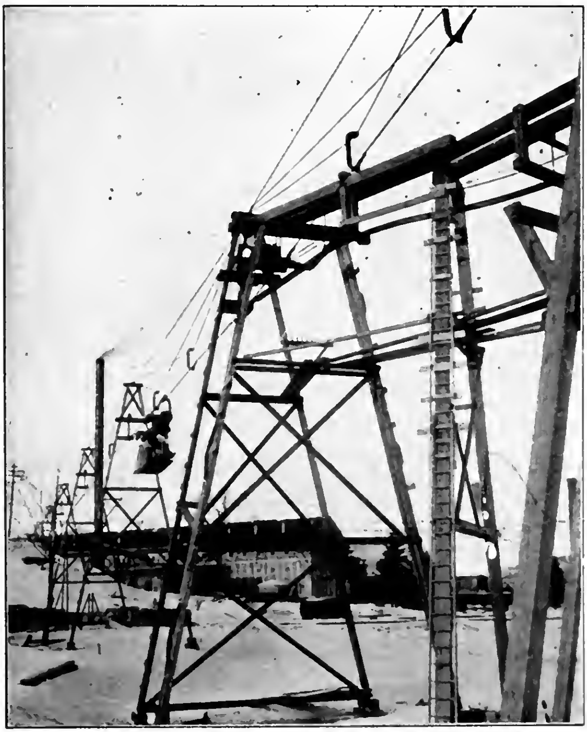
ent floors of the mills he enters; or, if he is out of doors, he makes landings on projecting platforms at each floor of a building, from which place the goods can be easily hauled into the room, the platforms, or telpher carriers being on trucks.



The operator, by pulling a cord, raises himself as well as the load, and then conveys the load to its destination. As well as the telpher, the hoist can also be controlled from the cab. One man can, therefore, attend to attaching and detaching the truck, raising and lowering the load, as well as the conveying. The machinery not only conveys, but also is equivalent to a movable freight elevator.

Before telpherage became a part of this manufacturing plant three teams were kept constantly employed in this transportation, two men attending each team. The cases were trucked from a store by hand, loaded onto the team and later unloaded onto the ground floor of a mill, where they

were elevated to the upper floor. A round-trip occupied twenty minutes. To-day the telpherman lowers himself through the roof of the receiving house to a position near where the goods are packed, personally loads his platform, or carrier, raises himself and load to his telpher by his hoist

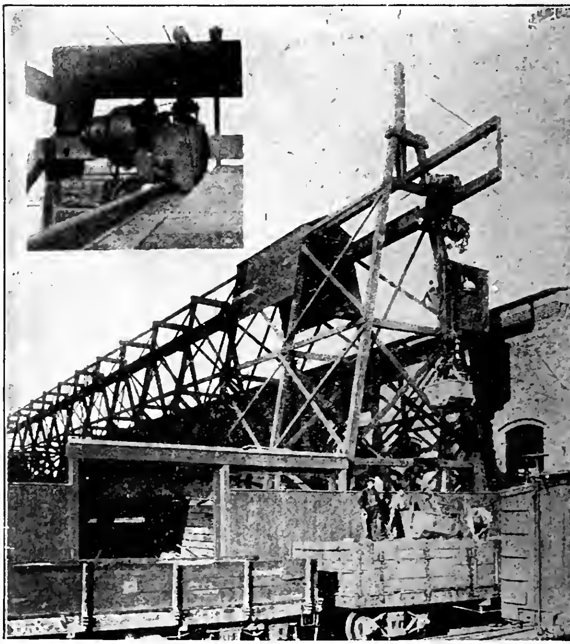


It is often necessary to convey from one group of buildings to another over railroad tracks or traveled roads or hills, and in winter above the snowdrifts This picture shows such a line in operation. Also an elevated track switch, where the line diverges. The track may be cable, T-rail upon stringer, or T-rail upon steel girder. Any reasonable load and speed of hoisting and conveying.

pendant, swings himself into his seat and in one minute is at the other end of the line, entering the second story, where he also serves the first by his self-lowering attachment.

This operator makes a round trip in five minutes, accomplishing with his telpher apparatus the entire work formerly occupying the time of six men and four horses.

The semi-automatic line as shown in this picture is controlled by a man whose position is in the small house on the trestle. When the bucket is filled, the operator, who over-



Height of track, 50 feet; load, 2,000 pounds; speed of hoisting, 60 feet per minute; capacity, 200 tons. Operation: Upon closing the switch the coal is elevated, conveyed to any location in the yard, automatically dumped, and the telpher returns the empty bucket for another load. Electricity does the work. Projecting track may be used over boats as well as over railroad tracks.

looks all parts of his problem, throws on his hoist switch, and when the proper height has been attained the telpher switch is opened and the machine runs down the line.

If desired, this installation may be automatic after hoisting is accomplished, the starting of the telpher being done by the opening of the switch by the hoist clutch contact, and the reversing of telpher movement being automatically

performed at the end of the line. In this semi-automatic installation, rapid handling is required. The operator in his tower stops the telpher immediately at any point, and, with an automatic device for dumping, the load is deposited at that point.

This installation shows three distinct economic propositions, viz., a nominal fixed charge in proportion to work performed, the effect of constant and rapid handling of coal on the vexing question of demurrage, and an unprecedented economy of storage space.

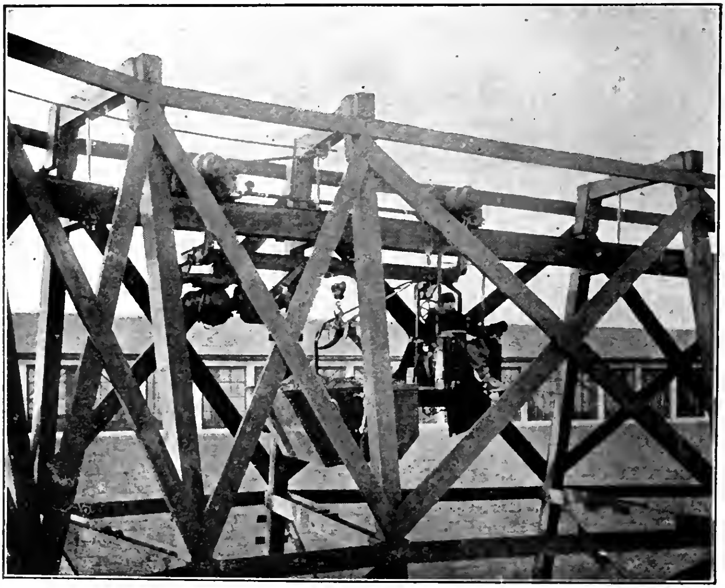
In the automatic installation are many interesting problems. Almost any height may be served by such an outfit, and the expensive old-time method of lowering and raising by elevator is entirely obviated. A large woodworking establishment receiving two cars of small worked wood daily, employed lumpers to back the material in baskets from the car up a flight of stairs, across a yard and into a workshop. It did not occur to the management that this was an expensive method of handling, although ten men were engaged in the operation. Perhaps the management were philanthropists, and wanted to keep those men employed; but we live in an age of competition; we are forced to be selfish, and in this case that very selfishness resulted in a humanity far exceeding the efforts of the management.

It became necessary to treat the material at the factory, where before it had arrived treated, and in the new arrangement the material had to be carried to the roof of a building and dropped into bins. This meant an increase in the lumpers from ten to eighteen; and although the men received but $1.50 per day, each, eighteen of such chaps cost money to maintain.

Telpherage was installed. One man filled a bucket with the material, threw on the hoist switch, then went to work filling another bucket. The electric hoist raised the load to the required height, the telpher switch was opened automatically, and the machine departed on its way. The run across the yard was made at 40 feet in the air. An automatic tripper was set at a special bin among the twelve

bins, the load was automatically dumped into the desired bin, and the machine arrived back to the starting point just as the second bucket was filled and ready for transport.

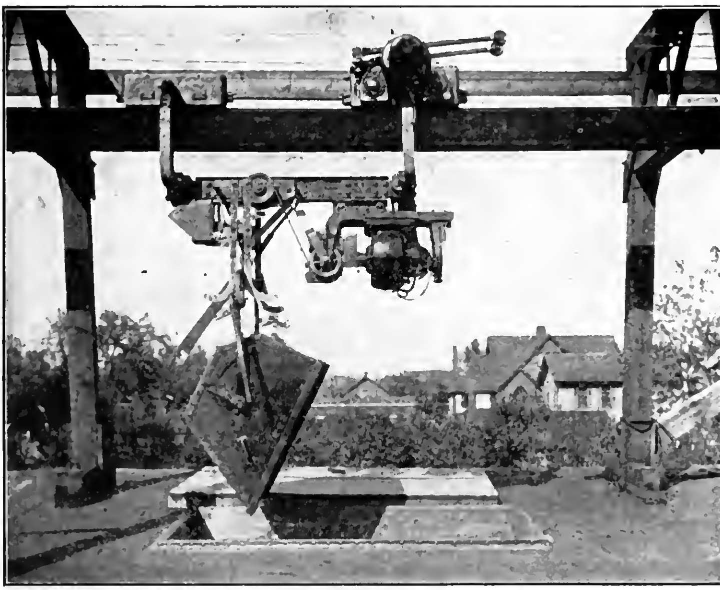
The installation caused much unfavorable comment from the lumpers, but it reverted to their good. When no longer able to do their habitual work, they cast about for something else to do, and all but two of the ten found more re-



Where there are heavy grades, the double telpher is used; that is, the trailer is replaced by telpher the same as a motor is placed upon both the front and rear axles of an electric street-car. Steep grades are easily surmounted. Both telphers are operated by the telpherman from his seat by the cylinder magnetic blowout controller. The full load is now passing from the cars to the hopper above the boilers

munerative labor on more important work in the same establishment. They could have done this new work before, but having a job they did not think it worth while to better themselves. Indeed, I understand that one of those former lumpers has so far advanced his condition that he is now running for alderman in the city where the plant is established. If he wins out he may place the entire credit to

telpherage. The two exceptions to an improved social status from this installation got work in another factory as lumpers. You know that lumpers we will have with us always. Over buildings, around corners, across rivers, sometimes bracketed to the sides of buildings, at other times supported in the open land by A bents; using the less val-

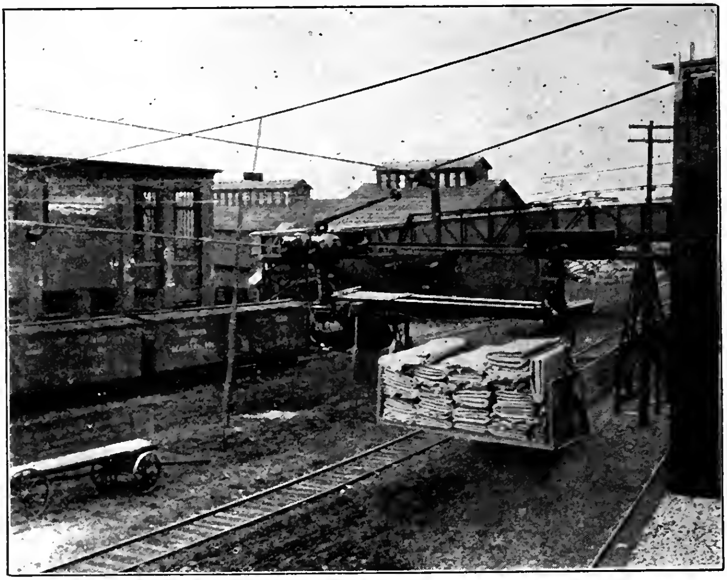


The single-motor telpher, the trailer, the swinging downcomes, the electric hoist, minimum headroom, one sheave type and the automatic control. By moving a single switch, located at any convenient point, the telpher is started, stopped and reversed, and the same is also true of the raising and lowering by means of the electric hoist; all that the operator has to do is to move the switch. At the end of the line, dead sections stop or reverse the telpher. Such lines, with the electric hoist, are independent of distances and curves. The opening in the roof of coal shed is uncovered for receiving the coal.

uable ledge for its "way;" running onto branch tracks by switches which the telpherman himself operates, opening and closing doors; running the entire length of storehouses and picking up a load without a particle of previous preparation—such is telpherage. In-and-out handling, it is the same to telpherage, whether the distance is 50 feet or

1,000; whether the haul is back and forth between different departments, or over the full length of the line, in whatsoever work it is employed, the effect is the same. Supplying the most effective mechanism for the action of the most inexpensive motive force the world has ever known, cost of transportation is decreased.

Automatic control of telpherage from any convenient point is accomplished in a very remarkable though simple manner by the use of an electrically-operated switch which has been called into existence by the requirements of tel-

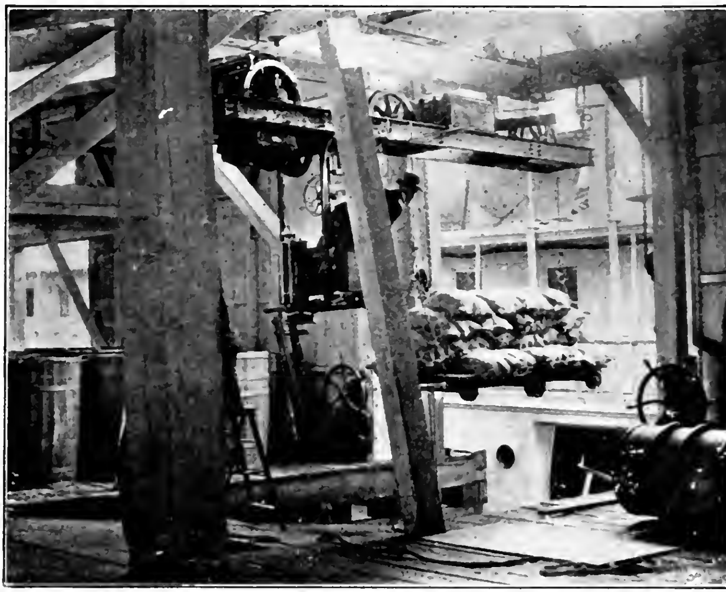


Paper pulp from one mill to another during process of manufacture. Automatic line with electric hoist.

pherage. By this attachment, working in conjunction with an ordinary controller, the direction of travel of either telpher or electric hoist may be changed, or the speed may be regulated, by the movement of a single controller handle. Telpher or hoist may be started, stopped, reversed or speed regulated wherever the machine may be on the line, although the operator is at his controller at some fixed point, or, if desired, the operator may start the machine, leaving it to its

own directorship, and it will traverse the line, whatever the distance, automatically deposit its load, reverse its direction and return to the starting point.

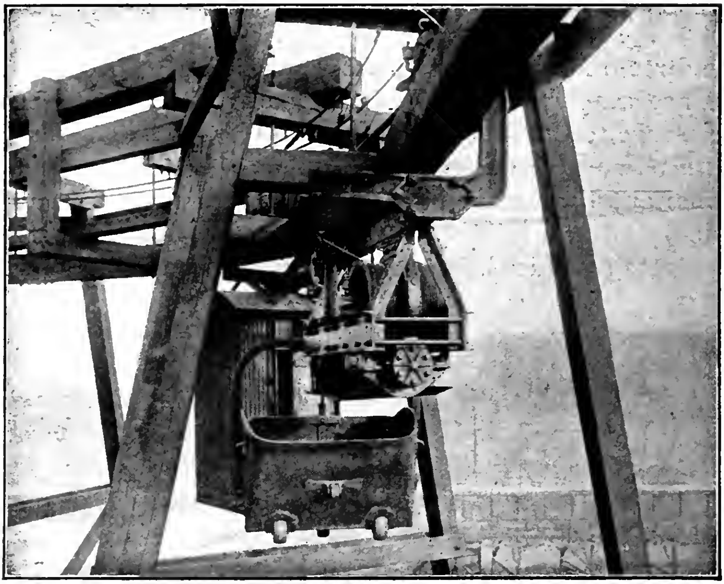
Only two trolley wires are employed in this control of telpher and hoist movement. When one considers that in ordinary electric railway practice four wires are necessary in the reversing of each motor, independently, it will again be



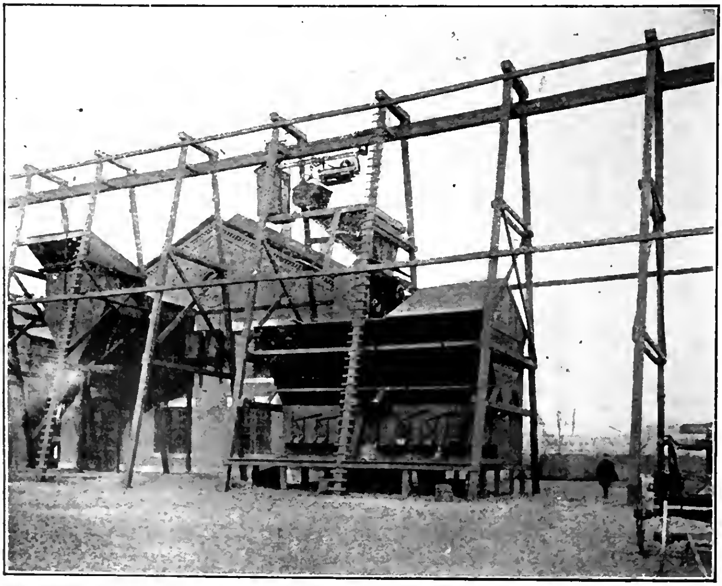
Taking freight from or lowering to the side ports of a steamboat. In unloading, the material is raised and then conveyed any reasonable distance. Load, 6,000 pounds; speed of hoisting, 60 feet; speed of travel, 1,000 feet per minute. Independent of fall of tide. Track can be extended so as to take load directly to or from barges or floats. In one telpherage installation one man replaces sixteen.

seen that telpherage is an unequalled vehicle for the action of electric energy.

Concerning strictly the method of hoist operation, and especially in semi-automatic installations, each machine is supplied with a small cylinder switch, which is manipulated by a solenoid working against a spring. Suppose the load is about to be lifted. By infusing power through a station-



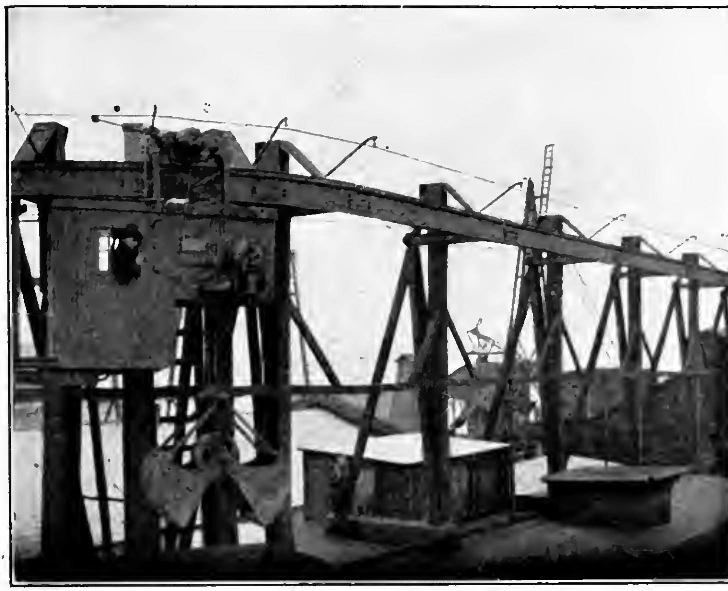
Telpher, hoist, bucket and enclosed cab upon a curve. Large drum, minimum headroom hoist Electricity can as easily hoist and transport six tons as one.



Gas works' telpherage. Applied to the hoisting, conveying, screening, depositing and storing of coal and coke and the removal of ashes. Also the quenching of coke and the transporting of the same to cars or wagons for shipment.

ary switch located at any point of the line, the solenoid of the automatic switch is energized and puts a tension on a spring. When the solenoid is de-energized the spring is released and rotates a cylinder which changes the various connections, thus reversing the motor.

It will thus be seen that with each cut out of power, there is a reverse of the hoist motor. The same principle is employed in the control of telphers in semi-automatic lines.



Clam-shell bucket, with double-drum electric hoist. The bucket is lowered open upon the coal or like divisible material, "grabs" the same, and the electric hoist closes the bucket and elevates the load, while the telpher does the conveying. Telpher upon a curve works equally well upon a grade. Load, with bucket, 3 tons. Speed, 1,000 feet per minute. Electricity does the work of eighteen men, one man directing.

A most important feature of this arrangement is that all breaking of the current is done at the stationary controller and never at the cylinder switch on the hoist, consequently there can be no arcing at the latter point.

If, when raising the load, the operator cuts off the power, the load stops where it is. Should he wish to go higher, he, having reversed the hoist movement in the cut-off, simply

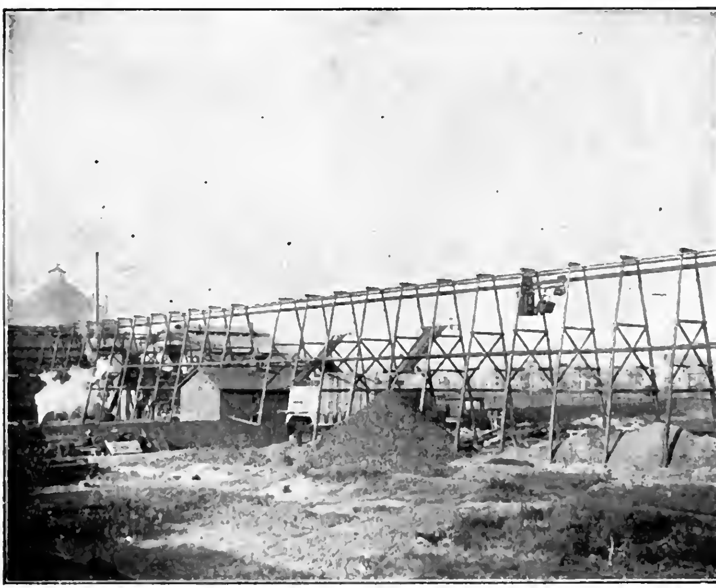
puts on power for a second, then again cuts off. The motor is now again reversed and with the next infusion of power the load elevating is continued. There are, therefore, but two trolley wires used in theentire operation, and no ground return. The same method of control is used for the telpher.

Large capacity coal or ash bucket, bottom dumping for small headroom. Bucket can be lowered 50 feet. Telpherman located most conveniently in the center.

A 10 horse-power gas engine is furnishing electric power for the lifting of a 3,000-pound telpherage load at a speed of 60 feet per minute, and a horizontal run at a rate of 1,000 feet per minute, at an expense of 30 pounds of coal per lifting horse-power hour, and 12 pounds for the horizontal horse-power hour. During a recent test of eight and one-half hours' continual running in a ten-hour day, one-twelfth

of the time was occupied in the lift, ten-twelfths in the horizontal run and a twelfth was lost in the changing of loads. The average per hour consumption of coal in the horse-power working hours involved in the problem was $13\frac{7}{10}$ pounds, or an actual power expense of 30 cents for the day's work.

Telpherage is an innovation, but it has come to stay. The progressive president of a large illuminating plant once expressed a thorough knowledge of what was needed to

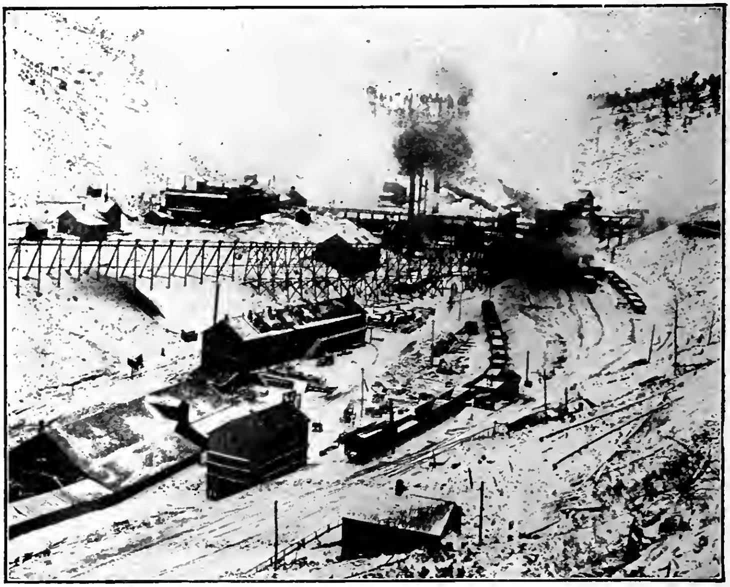


Telpher in gas works.

satisfy his requirements; "but," he continued, "I have heard of no apparatus on the market which will enable me to bring my several planes of operation into a comprehensive, and at the same time economical grasp. I not only need a conveyor, but one which will handle anything, anywhere, in a height of 50 feet."

Later, the gentleman found all necessities supplied in telpherage, through an installation of which he has practically doubled the efficiency of his plant. His coal-gas

retorts, water-gas retorts, screens, crushers, ash dump and coke store, although the individual serving-points vary in location from planes 9 feet below to 40 feet above ground, have been connected for handling, so as to produce of the whole an economic problem as simple as any feature in his actual manufacture.

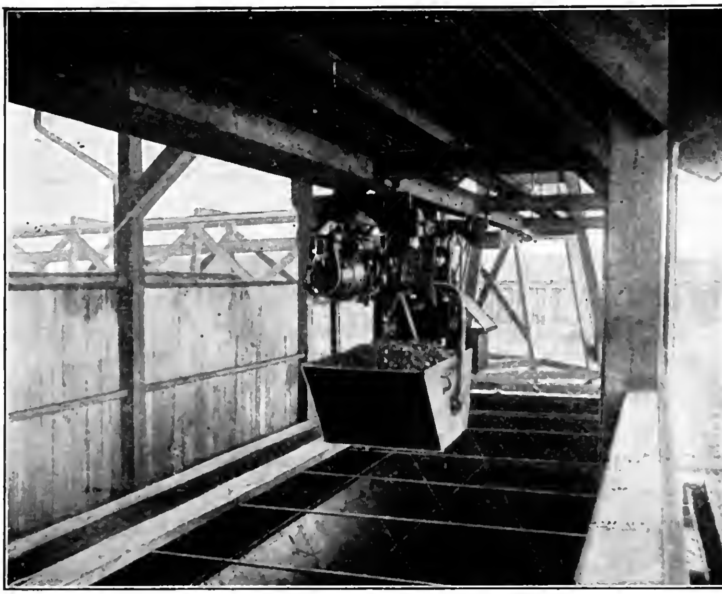


A long trestle upon the hillside for conveying a long distance not only coal and ashes, but any other products. This line is not only interesting on account of its length, but on account of the peculiar construction of the bents or supports, they being placed upon a steep incline.

It would be impossible to accurately compute the profit derived from his installation. The reduction in money expense is but a minor part, though twenty-five men and four horses would not accomplish the work done by the machine in its day and night shifts. From quenches 6 feet below ground 1,400 pounds of coke are delivered to the charging holes of the water-gas retort 40 feet above ground, the operation consuming but three minutes, though the effected points are 400 feet apart and two right angle curves intervene. Duties are performed by telpherage, which pre-

vious to the installation had no existence, but which, having been made possible, tend to produce that result in the yearly balance sheet which all live managers and presidents are striving for.

The practical value of telpherage has been so thoroughly demonstrated that you electricians who have to do with traction will surely hear more of it than has been explained



A ton of coal just before being dumped into the steel hoppers. The coal is hoisted from the cars by the portable electric hoist shown in the foreground of the picture, telphered 1,000 feet up a steep grade and around curves, to be placed in the hoppers elevated above the boilers. The empty bucket is then returned for one filled. Electricity does the work. One man only is necessary.

to-night. Obviously, telpherage could not have reached its present stage of perfection with other than electric power, but, to return the compliment, no other mechanical device has been created which so splendidly attests to the subtlety of the unseeable motor force. Three distinct operations hitherto considered subjects for separate mechanical treatment have been joined in a system, whose machinery pre-

sents a compactness of design, an enormity of efficiency and an economy of operation which is unequalled among transportation devices.

In addition to the lines as shown there is also what is called a moving telpher track. This is a section of track which is placed between the two side tracks, something the same way almost as a crane, with the exception that the telpher passes upon the side rails and across this movable tract to the other side. In the handling of miscellaneous freight by means of this moving track, goods can be lowered or raised from any portion of the floor or yard, and this is done without switches and without a multiplicity of tracks. The technical term for this is movable telpher track or space-covering track.

THE GROWTH OF THE SOFT COAL INDUSTRY.

To show what an immense figure the soft coal tonnage has reached one has but to regard some recent figures. The production of bituminous coal in the United States last year was 285,000,000 net tons, an increase over 1899, five years ago, of 94,000,000 tons, and an increase over 1893 of 155,000,000 tons, or much over 100 per cent. The present year will probably show a falling off, but not nearly so much as some people think. Certain it is that the tonnage of the soft coal carriers as yet shows no material decrease as compared with the corresponding period of last year. The tonnages are always about a month in arrears, and the reports for the month ending June 30th and the year to that date will show some falling off, but we shall be surprised if the total for the year 1904 shows less than 270,000,000 tons of soft coal produced. That is a reduction of 5 per cent. from last year's figures. The per capita consumption of coal shows an increase as steady as the growth of civilization, and will not cease until inventors cease from their labors and machines are discarded in favor of a return to hand-work. Even in coal mining itself there is a marked increase in the use of machinery in and about the mines, and the coal used for colliery consumption is larger every year, though the result of this innovation is a reduced cost of operation, and in some cases better prepared coal.

In 1880 the production of bituminous coal per capita was about ¾ ton, while in 1903 it was about 3½ tons per capita, and even should there be no greater increase in per capita consumption during the next ten years, the production by 1914 will be not less than 350,000,000 tons, as the population of our country at that time will be at least 100,000,000. But the accelerating rate of growth and the enormous expansion of our industrial development, the wonder of the world, give reasonable ground for believing that ten years hence the United States will be mining much beyond 400,000,000 tons, and possibly not far from 500,000,000 tons a year.—*Iron Age.*

Mining and Metallurgical Section.

Stated Meeting, held Thursday, April 21, 1904.

The Copper River Country, Alaska.

By W. R. Abercrombie, Major U. S. A.

General Introduction: Alaska was discovered a little over a century ago by Russian fur hunters. Sailing east from the coast of Siberia they first came upon the islands of the Aleutian Archipelago, which they took possession of in the name of the Czar of all the Russias.

Having established themselves on these islands, and having thoroughly subjugated and partially christianized the docile natives, they pushed farther east, found and explored the extensive coast of the mainland, and after many hard fights with the warlike tribes of those regions, established ports on Behring Sea and the North Pacific. The Russian Government granted to those early adventurers special privileges in this territory which they had discovered for the Crown. Thus was the foundation laid for the famous Russian-American Company that held almost undisputed sway over Alaska until it was purchased by the United States in 1867, through the foresight, diplomacy and wisdom of Hon. William H. Seward, then Secretary of State.

Under the suffrage of the Emperor of Russia the company named enjoyed positive power and ruled the country with a rod of iron. Not only did it have absolute right over territory, but over everything except the unexplored region of the far interior and the many tribes of free savages therein, who recognized no master. Nothing was made public except such affairs connected with the fur trade as the company saw fit to permit to be published; hence, when Russian America became a portion of these United States little or nothing was known of the interior, and from 1867 to 1869 nothing of particular importance enlarged our geographical knowledge of this newly acquired

territory. On the sixth day of April, 1869, Captain Raymond, Corps of Engineers, U. S. A., and party left San Francisco, Cal., on the brig "Commodore," on the deck of which was a 50-foot stern-wheel steamer, "The Yukon," bound for St. Michael, mouth of the mighty Yukon River, the waters of which this small craft was to be the pioneer in navigating. On the 26th of June, 1869, this party, after an uneventful voyage via Sitka, arrived at St. Michael, and on July 1st steamed forth to ascend the Yukon, 1,040 miles. Thirty days later Captain Raymond and party arrived at Fort Yukon, terminating successfully the first journey by steam on the Yukon River.

The object of Captain Raymond's mission to Fort Yukon, the most northwesterly station of the Hudson Bay Company, was to determine astronomically the geographical position of that station relative to its location in our newly acquired territory, and from that time to 1883, fourteen years, no one appears to have been disposed to undergo the hardships incident to the exploration of this great unknown region.

On the 22d of May, 1883, we find a hardy band of explorers headed by First Lieutenant Frederick Schwatka, Third U. S. Cavalry, A. D. C., who had previously made extensive explorations into the Arctic from the Atlantic Coast, sailing from Vancouver Barracks, for the head-waters of the Lynn Canal, a long, narrow fjord terminating in the Chilcoot Inlet, Southwestern Alaska. The Raymond expedition of 1869 developed the fact that to ascend the Yukon it would take about the entire season to fight the swift current; and after a careful study of the geographical features of the drainage of the head-waters of the Yukon, Lieutenant Schwatka conceived the idea of crossing the portage through the Chilcoot Pass, from the head of the Lynn Canal to Lake Lindeman, a tributary to the Yukon, and going down stream with the current through the Yukon Valley to St. Michael. On the 10th of June, 1883, the Schwatka party, having disembarked at Chilcoot, started, together with a number of Chilcoot Indians as cargo carriers, up over this now famous Chilcoot Pass;

arriving at Lake Lindeman, the Indians returned to their country, leaving the white men to pursue their journey. In due time this party landed at the mouth of the Yukon, performing successfully one of the most remarkable raft journeys on record.

The exploration and mapping of the Yukon Valley disclosed the relative position and course of this river to the trend of the Pacific Coast line from Lynn Canal to Cook Inlet to be parallel. A glance at the map of Alaska will show a continuous curvature to the westward. It will also be observed that from the summit of Chilcoot Pass to Mount St. Elias, the eastern slope of those mountains are a portion of the Northwest territory, a province of Canada; so that while the Schwatka exploration developed the Chilcoot Pass as a passable route for the American miner and trader to journey into the Yukon Valley, it also developed the fact that from the crossing of the summit of the Chilcoot to the intersection of the national boundary line with the Yukon River at Eagle City, more than 400 miles of the Yukon Valley lay in foreign territory. The question then arose, where should we find an "all-American route?" It was at this period of the development of the geographical features of Alaska that I became identified with the exploration of that country, covering a period of some sixteen years.

The result of many conferences relative to the possible discovery and location of a route from the seaboard to the interior of Alaska through American territory, which would be free from ice and available for the traveler all the year round, resulted in my exploration of 1884, the object of which was to explore and survey the Copper River Valley to the Yukon drainage.

THE 1884 EXPLORATION OF THE COPPER RIVER DELTA AND PORT VALDEZ.

On June 1, 1884, I left Portland, Ore., with my party, which consisted of four assistants, on the steamer "Idaho," James Carroll, Captain; the understanding being that the steamer would take my party some 50 to 60 miles

up the Copper River, where we were to disembark. At the date above mentioned little or nothing was known of the interior of Alaska, and I was instructed to confine my explorations to the Copper River Valley, to ascertain the number, character and disposition of the various tribes of Indians, the feeling which existed among them towards the white man, their mode of life, means of communication with the outside world, and what had been their attitude toward the Russian Government in the past. I was to note the geographical features, mineral and agricultural resources and the various kinds of fish and game existing in that country; in fact, to collect general information. Steaming down the Columbia River, we passed out into the Pacific and laid our course for the Straits of Fuca, through which we passed to Victoria, then the principal town in British Columbia. Leaving this quaint old place, we steamed northward through the inland passage to Sitka, Alaska, at which point we expected to get a Russian pilot to guide the steamer up the Copper River; having secured a Russian half-caste, who claimed to have the necessary knowledge, we left the beautiful harbor of Sitka, and steaming north on the morning of June 16th, my party arrived at Nuchek, a trading station of the Russian-American Company on Hinchenbrook Island. Our pilot informed us that this was the place known to the Russian traders as the Copper River country, and after interviewing the agent in charge of the station, we learned that we were on an island about 60 miles from the mouth of the Copper River, but just where it was he did not know, but I could undoubtedly get Indians to guide my party to it. In the meantime, our outfit having been landed on the beach, we stood with some 80 to 100 natives watching the steamer "Idaho" steam south to civilization, the white man's country, and the situation was not pleasant. As this was the first steamer to visit this section, it was curious to note the effect on the natives, who thought it was some sort of a whale that the white man had captured and made a slave; and, as we watched, a parting salute was fired, as was the custom in those days, and all the natives ran into their village and hid in their huts from evil

spirits. One word as to the history of this village, which was discovered by Cook between 1776 and 1779. In 1778 the Russians built a log fort as a trading station. In 1796 two expeditions were outfitted at this point to explore the Copper River Valley, but both failed. Other Russians followed without success, and in 1847 Rufus Serebevinkoff, a half-breed and a graduate of a school of commercial navigation of St. Petersburg, Russia, explored the Copper River Valley, and was probably murdered by a chief of the Chettyna Indians, as his notebook was afterwards given up by the coast Indians who got it from the Copper River natives.

With the history of these failures before me, I, on the day following the landing of my party, gave a "potlatch" to the natives in accordance with their custom, which is about the same thing as giving a political dinner with us. At this feast I made known my mission largely by signs, and engaged some of the natives with their boats to assist us to reach the Copper River. These arrangements consumed almost the entire day. As the white men were not familiar with the baiddirra, a native boat which consists of a birch frame over which is tightly drawn a covering of sealskin, I purchased an old Russian boat for myself and assistants, and with this equipment of sea-going craft, I left Nuchek on the morning of June 20, 1884, coasting along the shore of Hinchenbrook Island to the north and west into Prince William Sound to Point Johnson. The water was very clear, the bottom being plainly seen at 25 feet. Passing through a narrow channel between Hinchenbrook and Hawkins Islands, my party camped on a small island close to the mainland. With an early start next morning, to take advantage of the tide, we pushed on in the direction indicated by our Indian friends. Toward the mouth of the Copper River, I noticed that the water was not so clear, nor was there any seal or fish to be seen. During the afternoon our Indians seemed much excited, until finally our Russian ship's boat, which drew probably 18 inches of water, grounded, notwithstanding the fact that we were some two or three miles from land. One of our party got out of our

boat to sound with a pole for deep water, as the color of the ocean had now changed to milky gray. Being intent on watching his movements, we were greatly surprised on looking out seaward to see mud flats for miles.

After some hours sign-talking with the Indians, I learned that we had arrived at the mud flats at the mouth of the Copper River at low tide and that we must wait for the flood tide to enter the river itself. In the evening we drifted up with the incoming tide into one of the numerous sloughs which compose the mouth of the Copper River, and camped near an Indian village of six or seven barraboras or houses, each house being occupied by from ten to fifty natives, all of whom turned out to greet us, much to the dismay of our island natives who represented these Copper River natives as a ferocious lot who had killed all the Russians that had ever come within their reach; and from the lively manner in which they paddled out to sea, I imagine they thought the American would fare no better. The first thing to be settled was the "potlatch" which the head men of the village decided in conference would be the next afternoon, the natives giving an entertainment in honor of the white chief in the morning. Accordingly, about 10 A.M. the next day, three of the old men paddled over in their canoes to escort us to their entertainment. As everything in the eating line is most dear to the native, I decided to go to the reception alone and leave my assistants to watch the provisions. After many explanations, this was agreed to by the old chief in a half-hearted way. Getting into a canoe I paddled over to the largest house, which was about 40 feet square, on the four sides of which were built a series of cells with doors. On top of these cells lived the men, while the women and children lived below. The entrance was through a hole about 2 feet in diameter, over which hung a skin of some animal; the only light came from an aperture in the roof, which also allowed the smoke from the fire to escape. I suppose there were over a hundred people in this house; the stench was of a quality not to be forgotten. In front of the door of this barrabora was left space enough for one native to enter and dance to the music made by some eight or ten who chanted

in that dismal monotone peculiar to natives the world over. The characters impersonated were the bear, moose, fox, sea otter and whale, etc., with some portion of the animal, usually the skin, used as a decoration for the actor who would chant of his prowess. During the impersonation of a whale, on the day in question, the native told how he came out of the Arctic Ocean, where darkness prevails from October to May, to a village of the island natives, where a mighty chief had a strong box in which he kept the sun, moon and stars. This chief had an only son, whom he loved dearly. The whale became acquainted with this boy during a storm when the boy was out on the ocean in a kyac, sea-otter hunting. The whale learned from the fox, who knows everything, as he is constantly nosing about, that the chief was away in his big war canoe, so he swam into the bay where the boy lived and called to him to come and get on his back and take a ride. He gave the boy a short ride and came back. The boy urged the whale to continue, as he had never ridden so fast before; the whale refused, but agreed to after a while if the boy would let him see the box of light. The boy called to a squaw to come down to the beach and hold up the box so the whale could see it; when she did so, the whale rose out of the water, thereby creating a mighty wave, which ran up the beach with such force that it threw the woman down. As she fell she dropped the box on a stone and broke it open, when the sun, moon and stars escaped and ran up into the sky never to return. For this act the whale was turned into a great chief with many dogs and big canoes as a reward for his service to mankind in establishing the sun by day and the moon and stars by night.

In the afternoon all the natives came to my camp, where we gave them probably their first taste of civilization, consisting of crackers and bacon. After the "potlatch" a general council was held. I explained to the natives that we wished to ascend the Copper River and wanted them to help us, and that we would pay them in provisions. We had no difficulty in arriving at an agreement whereby they were to serve us. On their part the old chief explained that

the Copper River was a very dangerous body of water, and that many Russians had been killed in attempting to ascend it, and that their people had often been held responsible for their death; whereas, as a matter of fact, the river had swallowed them up. To show the simplicity of these people, while we were having our conference my topographical assistant was working up the latitude and longitude by means of an artificial horizon, which consists of a tank of quicksilver enclosed by two heavy plate-glass windows, being about 4 by 8 inches. One of the natives, accidentally looking into the artificial horizon, saw the image of the sun, which created great excitement, following, as it did, the story told in the morning entertainment of the box of light. This instance was taken advantage of to assure the natives that we had provided against all accidents from drowning in the Copper River. This was followed by a present of a blanket to each chief, when the council was closed by the natives agreeing to start early next morning. We broke camp at sunrise, our transportation consisting of the Russian boat and some fifteen or twenty little canoes. Passing up on the slough for some 8 miles, we came to within a mile and a half of the mountains forming the western side of the Copper River delta. From this point we cut a trail to the mountain through the heavy growth of alder brush, and climbing up the base some 500 or 600 feet, we obtained an excellent view of the Copper River delta, which, at this point, was some 30 miles broad, and consisted of a series of small streams and sand-bars as far as the eye could reach. Our discovery was anything but satisfactory; where we had expected to ascend the Copper River for some 70 or 80 miles in a steamer drawing 18 feet of water, we found that it would be necessary to proceed with the lightest-draft canoes for some 90 miles to reach the head of this delta, where the Copper River Valley proper would begin.

Having worked our way some 15 miles farther up stream, we encountered a new feature, a new obstacle to our navigation. Small pieces of ice were constantly being met with, and on the afternoon of the 14th of July we were forced to land and pull our canoes out of the river to allow the ice

floe to pass by. Early on the morning of the 15th we broke camp and continued our journey, our progress being very slow, owing to the constant passage of ice down the river. During the afternoon of this day, one of the small canoes belonging to the natives was crushed in the ice, and the poor fellow drowned, while our larger boat was carried some miles down stream. From this on it became a constant fight. At times our canoes would have to be beached and drawn for half a mile or so over the sand-bars to other streams, in crossing one of which another native was drowned, when the remaining thirty or forty absolutely refused to proceed farther until the water had fallen.

From July 16th to 19th it rained almost constantly; the river was many times blocked with icebergs, rendering navigation impossible. On the night of July 21st I witnessed a most interesting spectacle; first large bergs came sailing majestically down-stream, passing and repassing each other as the water forced them from one side of the river to the other. On many of them were large bowlders that looked not unlike passengers. These would occasionally tilt in striking a sand-bar so as to throw the bowlders into the river. Then, again, two large bergs would come together with a shock that would make the ground tremble. This, taken together with the roar of the water, had a tendency to make us a little timid in the handling of our boat. This continued until the 31st of July, when for some reason the ice floe in the river ceased.

In the afternoon of this day a bidarra loaded with furs and manned by ten upper-river natives came down the river. Seeing our flag, they landed and were very much surprised to find that we were white. After some hours' sign-talk we made them understand that we wished to go up into their country and to be their friends. With a liberal allowance of black tea, of which they are very fond, we talked the matter over, and they agreed to take their furs on down to the coast tribe, do their trading and return and assist us. Later on these natives returned with a few of the coast Indians with them.

Having cut a trail to the Miles Glacier, we started out

with the intention of making a portage over that ice field, landing our canoes above rough water. But after traveling some 12 miles over this glacier, it became so cut up with crevasses that we were forced to return. The head of the Copper River delta was originally blocked by the Childs Glacier coming in from the west and the Miles Glacier coming in from the east. These glaciers, in their earlier stage, brought down with them immense masses of moraine, over which the river ran until the current carried the bowlders and silt off faster than nature could deposit it, then the water cut through the ice, and at the period when we were there had left the face of the Miles Glacier some five or six miles long and the Childs some three miles long. The ice floes that we had met with during the summer were occasioned by the river digging the gravel and bowlders out from under the faces of these glaciers, which would average between 300 and 400 feet high, when a portion or the whole face of the glacier would fall forward into the river with a shock and detonation that could be felt and heard for over 20 miles. I have seen the river bed below Childs Glacier almost entirely bare, when, with a roar and grinding noise almost indescribable, the flood of water and ice would come rushing down stream, grinding up everything before it. It was in these ice jams, the Indians claimed, that most of the Russians had met their death. To avoid these, it would be necessary to travel over both the Miles and the Childs Glaciers, which our efforts had proved to be impossible.

Returning to the point of the river just below Miles Glacier, we waited a favorable opportunity between the ice gorges and crossed over to the left-hand side with the upper river natives, and hauled our boats some 8 miles up-stream to what is known as the "Abercrombie" Rapids. This is a seething whirlpool some 3 miles long, the Miles Glacier having backed the river up. It now became evident that as a route of travel from the coast to the interior, the mouth of the Copper River was valueless.

Looking down toward the sea on the 1st of September, we could see miles upon miles of sand-bars separated by

small streams, into which the Copper River divided itself after leaving Childs Glacier. Through this network of small streams it had taken us three weary months to cover a distance of 90 miles.

By this time we were somewhat stiffened by exposure to rain and wading in the cold, icy water, and considering it wise to return to the coast, we waited a favorable opportunity to run by the glaciers. So on the morning of September 1st we shot by the face of Miles Glacier without accident, and, landing our topographical assistant with his field notes, we ran down by the face of Childs Glacier. The sensation in passing the mighty walls of ice was sickening; the current was so swift, some 6 or 8 knots an hour, that by looking at the shore we apparently flew, yet while looking at the glacier we appeared to be standing still.

Passing by this mass of ice we arrived in our former camping place in ample time to regain our old Russian boat and re-embark with our topographer ahead of the ice floes.

On the following day we arrived at Alhanic, having covered in two days down-stream the distance that it had taken us three months to travel up-stream.

Leaving the mouth of the Copper River the following day, we proceeded to our old camp on Hinchenbrook Island, where we arrived on the 10th of September after encountering some heavy storms in Prince William Sound.

From a half-breed Russian, who had been in the employ of the Russian-American Company, I learned that there was a Russian at Port Fidalgo, a tributary to Prince William Sound and some 70 miles from Nuchek, that could probably give me some information of a route from Port Valdez to the Copper River. So on the 11th of September, I left Etches in a canoe with four natives, and the following day arrived at the barrabora of one Plutoniff, a Russian exile, from whom I learned that prior to 1868 the Copper River natives came down to the head of Port Valdez through some pass in the mountains to trade their furs; but during that year the smallpox had broken out among the coast Indians, which had swept away the entire village at the head of Port Valdez.

Plutoniff did not know where the pass was, nor did his sons. However, by persuasion and the use of considerable black tea, I induced the old man to send his sons with me to the head of Port Valdez in the hope that I might there find more information.

Proceeding from Port Fidalgo to Port Valdez, I entered and explored the upper end of that "Fiord."

Arriving at its head, we passed into a small lake which lay at the foot of an immense mountain. Climbing this mountain with my native guide, he pointed out to me the volcanic Mount Wrangel and the general direction the natives used to travel in going back to the Copper River. With this meager information, I returned to Nuchek, where, awaiting my arrival, I found the sealing schooner "Leo," which was to take my party back to Vancouver Barracks, where I arrived in the month of December.

The sum total of the exploration of 1884, while it developed the topographical features of the Copper River delta and Port Valdez, were of a negative character so far as developing an all-American route was involved.

It was not until the year 1898 that this subject was again taken up by the War Department, when, owing to the friction between the American miner and the Canadian official in the Klondike region, the Secretary of War was directed by a Senate resolution to explore all possible routes of travel from the Gulf of Alaska through to the Yukon River with a view of discovering and locating an all-American route to the Yukon.

In the month of February, 1898, I was summoned to Washington for a conference with the Secretary of War and the General of the Army relative to the continuation of explorations from Prince William Sound to the Yukon River.

To carry out this work, the War Department had imported from Norway 557 reindeer, with sleds and equipment, and 113 Lapland drivers, herders, etc., with a view to using this transportation in pushing forward the explorations of an all-American route. After my conference, I proceeded

to Seattle, Wash., and organized one of three expeditions that would take the field. On the 8th day of April, 1898, I left Seattle with my expedition, following up the inland passage between Vancouver, Queen Charlotte, Admiralty, Barnhoff and Chicagof Islands and the mainland, leaving this passage at Cross Sound. From thence I proceeded over the Fairweather grounds, which lie south of Mount Elias and the Great Malaspinia Glacier and Kyak Island to Prince William Sound.

It was found, on arrival at the Haines Mission, that the reindeer for this work, owing to their long ocean passage and journey across the continent and the lack of proper food, were wholly unfit for further use. I landed my party at the head of Port Valdez, and at once organized small parties to push forward such explorations in Prince William Sound and through the near-by mountain passes as could be made without the use of pack-animals. I found, at Valdez and scattered over the Valdez Glacier, some 4,000 gold seekers, who had chosen this route with the idea of reaching the Yukon River. All were provided with small hand-sleds with which to transport their goods into the interior, intending, after the snow had melted, to continue their journey by pack, packing to some imagined point. Many had never been out of the sight of a factory chimney, and were wholly unacquainted with woodcraft or the ordinary means of traveling through new country. It is hardly a matter of surprise, therefore, to learn that 90 per cent. of these people never even reached the Copper River.

In the latter part of May, I took one of the various steamers that had come into Port Valdez with gold seekers and returned to Seattle, where I communicated with the Assistant Secretary of War, and received his sanction to purchase forty head of horses to push forward the explorations.

Leaving Seattle, I proceeded over the mountains to the North Yakima Indian reservation, and selected what I considered to be forty fair pack-animals, with which I left Seattle for Port Valdez in the latter part of June, where I arrived on the 8th of July. The glacier streams in and around Port Valdez had now become swollen to such an

extent as to render the crossing of them by pack-animals an impossibility without the construction of bridges. During my absence at Seattle, one of the party sent up through the Keystone Canyon, with instructions to cross over and follow down the Tasnuna River to the Copper River, had returned with the information that, barring the deep glacial streams to be crossed, there was no difficulty in reaching the Copper River from the head of Port Valdez. (This was the pass that I had attempted to find when accompanied by the two Russian half-breeds in 1884.) I now gave up all hope of reaching the Copper River by this route, as the season was so far advanced that it would be impossible to bridge even the smallest stream and obtain any results from exploration.

I then reorganized my party into four sections, one of which I took charge of, which was to take that part of the Copper River Valley from the head-waters to the point where we should strike the river after crossing the glacier. The second was placed in charge of Mr. F. C. Schrader, geologist, which was to explore and map that region along the Copper River south to the point reached by me in 1884. The third was in charge of Mr. Emil Mahlo, topographical assistant, who was to explore the Tonsena and Tasnuna River Valleys with a view to finding an outlet from the Copper River to Port Valdez. This work it was considered would practically take in all of the topography from a point about 180 miles north of the Copper River and 90 miles east of Port Valdez lying within the Copper River proper. The fourth expedition, under Lieut. P. G. Lowe, U. S. A., was to push exploration from the head of the Copper River to the Tomona River, and crossing that river, striking in somewhere on the head of the Forty Mile and down that stream to Eagle City, the intersection of the international boundary between Canada and the United States and the Yukon River.

On August 5th, notwithstanding that it had been raining and foggy for some five or six days previous, the four sections of this expedition moved up to the foot of the Valdez Glacier.

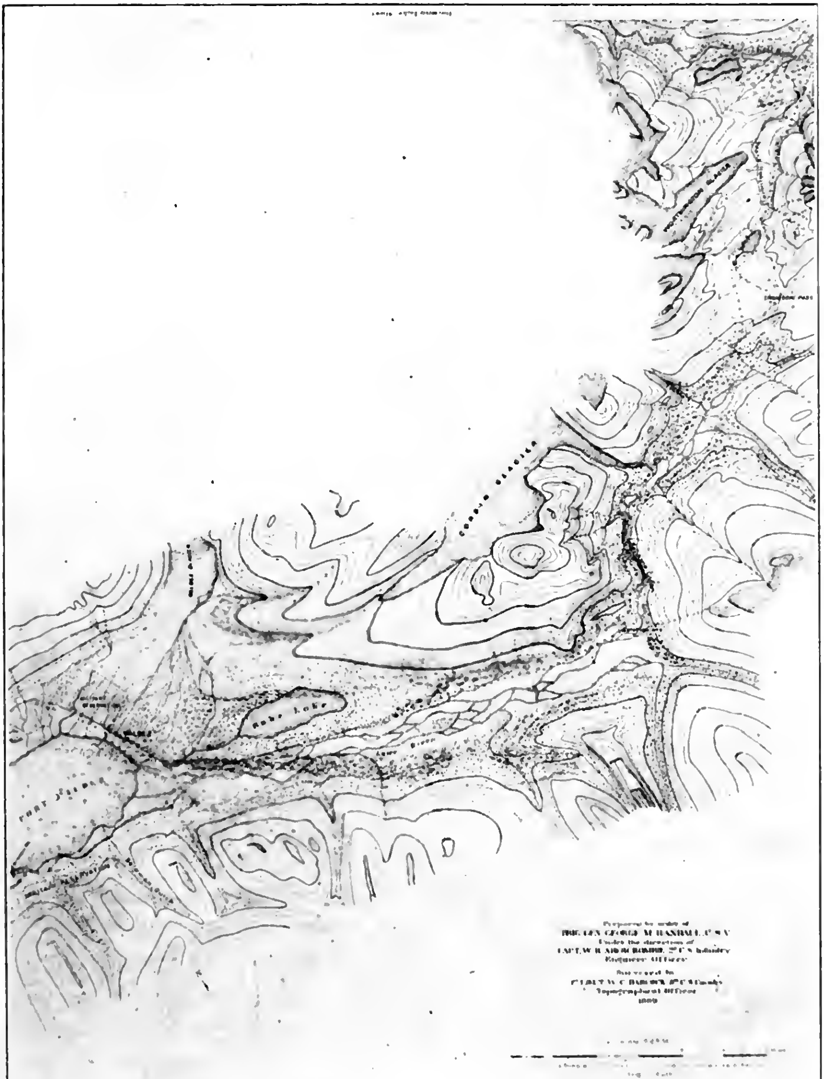
Prior to this I had kept men up on the glacier during clear weather building small stone monuments as guiding signs for us to follow in crossing over the mountain range. The Valdez Glacier, from its foot on the coast side to its termination in the Copper River Valley, is 30 miles long and 5,000 feet in altitude. This ice is formed, of course, by pressure, it being estimated that a column of snow 40 feet high with an atmospheric pressure of 15 pounds to the square inch will form ice by pressure. It is no uncommon thing on the summit of these mountains to see a fall of snow of 25 or 30 feet in depth. As the ice is formed on the summit it is forced into the valley below, and as it passes over inequalities in its road down to the low lands large fractures occur, which are known as crevasses; some of these on the Valdez Glacier were over 300 feet deep, and it was estimated that in some places the ice was over 800 feet thick. During the winter the snow forms an arch over these crevasses capable of holding the weight of a man or a horse, providing the tenacity of the snow has not been weakened by the sun's rays. It was by traveling over these snow arches that I hoped to take my pack-train of some thirty or forty animals up over this glacier and down into the Copper River Valley. The one great danger that I could not guard against was the shifting of the wind when the summit was reached, as the mountains for many miles east and west were one continuous mass of ice; hence the building of small stone monuments, which we hoped to follow should it become stormy during our passage over the glacier.

Everything being in readiness so far as our glacial experience extended, we broke camp at 5 A.M. on the morning of August 6th and started up the glacier. As we rode on the ice I asked one of the men whom we depended upon to guide us over the summit what he thought our chances were of getting through, and he replied that if the wind shifted in the pass and we lost our bearings, I would stand a good show of losing my pack-train and most of the personnel of the expedition; but if the wind held fair we ought to be in the Copper River Valley by the following day. For convenience in handling the animals I had divided the train

into five animals to each section, each animal being led by a man, with an extra man in reserve to assist in pulling animals out of crevasses should they break through the snow.

Passing onto the glacier the animals seemed to know instinctively that there was danger ahead, as they would tremble and keep their noses close up to the backs of the men who were leading them. Whenever they broke through a snow arch, as they often did, they would lie still until pulled out by ropes. As the expedition passed up through one crevass and turned to make an ascent of some 50 or 60 feet up a grade of not less than 45° onto a cone of ice, it looked very much as if we were trying to make the horses climb up into the sky, the dense fog and the ice being about the same color. Now and then a horse would lose his footing and slide down to the bottom with a rush, but never once did one of them refuse to climb out of an ice gush when called upon to do so, although many times they left a trail of blood behind them where they had been cut and bruised in their fall.

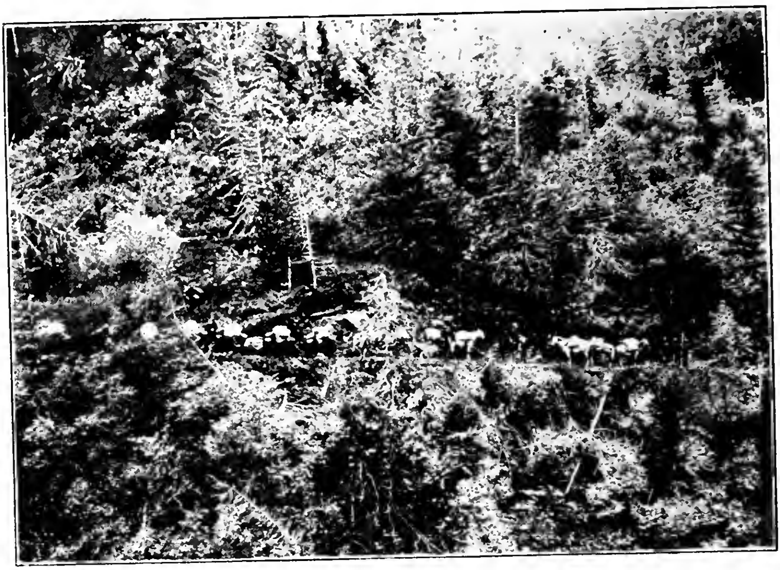
Arriving at the top of the first bench, one of the inequalities heretofore referred to, caused by the glacier passing over a reef of rock (in its passage down the valley), the fog was so dense that it was impossible to see more than five or six animals of the train at any one time. Every once in a while we found that the melting ice had caused one of the stone monuments, which marked the trail, to topple over, when a halt would be called and our guide go forward just far enough to keep within hailing distance, when having found another monument, we would again push forward. In this way the train was kept moving during the day and well into the night, covering some 18 miles, when it became so dark that we halted and stretched our picket line, and unloading the horses tied them together for the night without taking off their saddles. The rain was now coming down in torrents. Not only was the night black, but the fog that came from the melting ice was extremely cold and penetrating. Occasionally the glacier would crack as it settled in its passage to the valley below, with a vibration that would cause the men to stop in their tramp and the horses



Valdez and Thompson Pass Sheet. One of the many sections which, as a whole, form the map of the All-American Route.

to whinny with fear; then would follow the deafening roar as some thousands of tons of ice that had been detached from one of the hanging glaciers that fringed the mountain side, would come crashing down onto the main glacier. Towards morning some of my men became so chilled and tired that it was necessary to administer a little stimulant. It was observed on this occasion that there were few prohibitionists in the party. This night, like others, came to an end.

At daybreak we repacked the animals and proceeded on



A section of All-American Route through Keystone Canyon, 14 miles from Valdez.

our journey toward the summit. Four or five miles were covered when we came to a section of the glacier known as the fourth bench, which was so bisected with deep crevasses that it looked impossible to pass over them; but by taking the train down one long narrow peninsula and doubling back on another, we, after some hours of careful work, regained the level above. The mental strain at this stage of the journey was terrific. The horses and men were so badly used up that it would have been impossible for them to survive another night on the glacier, and our progress through

this network of crevasses had been so slow that I was afraid we would not cross the summit in daylight. We were now up about 3,000 feet in slush and snow about knee-deep. Bearing off from the fourth bench to the right we managed to get our train onto a series of snow slides and made fairly good time to the foot of the sixth bench. This was the last raise of the glacier, which was 1,100 feet in one mile, or a climb of almost 45°. The fog had now given way before a violent wind, and as the pack train crawled up this ascent they looked like little birds going over the snow. On reaching the summit the wind was blowing a hurricane into the interior, accompanied by gusts of sleet and snow, which, freezing as they fell, coated man and beast with an armor of ice. All thought of trying to follow the monuments was now abandoned, as it was impossible to do anything with the horses except let them drift with the storm, which, fortunately for us, was in the direction we wished to travel. After traveling some five or six hours in this storm we could feel that we were making a descent, and knew that, barring accident of falling into a crevass, we would soon be in the Copper River Valley. Following down the pass, the weather rapidly moderated until we came out into a clear sky, still above snow-line. Here the men and horses sank down into the snow for half an hour's delightful slumber, while back of us out of the canyon howled the storm as black as night. Following on down the glacier we soon made camp and all felt greatly relieved to know that we had accomplished somewhat of a task in bringing a pack train of forty horses over a glacier thirty miles long and almost a mile in height.

On the morning of the 8th of August we continued our journey down to Klutena Lake, and following the shore of that body of water, camped at the eastern end near the base of a high mountain, where we gave our horses a much-needed rest and ascended the mountain, where we got a beautiful view of the Copper River.

Locating the most prominent mountains as a guide for our future travels we passed on down to the Copper River, where our parties were to divide.

On the 23d of August Mr. Schrader and Mr. Mahlo started down the Copper River Valley, while I, crossing the Copper River, began my journey toward the head-waters. After some two days' travel, passing along the foot of Mount Drum and Sandford, I again struck the Copper River, a mere stream some 70 miles north from the point at which I parted with my assistants. Continuing my journey up one branch of the river, which afterward developed to be the Salina, I again came into a mountainous region, which

Mule train crossing Thompson Pass, June 1st, 18 miles from Valdez.

proved to be the main range of the Rocky Mountains. Camping at the foot of one of these high mountains I ascended to its summit, and with a strong pair of glasses was able to locate all the prominent features of the upper Copper River Valley.

Returning to camp, I found that we had but 25 pounds of flour, 5 pounds of bacon and a half pound of tea on which to feed myself and two packers on our journey back to our point of departure, which I estimated to be 175 miles dis-

tant. Starting at once for a new pass that I discovered in the Salina River Valley, we reached that stream about 30 miles above its mouth. Finding that greater progress could be made through the timber by stripping the horses of their loads, we made a raft, and placing thereon our camp outfit and saddles, I took charge of the raft while my packers started down the river bank through the timber, to meet again at the mouth of the Salina. Turning south down the banks of the Copper River, we pushed forward with all haste, fording and swimming the small streams, arriving at the mouth of the Klutena River, the point at which we had parted with Mr. Mahlo and Mr. Schrader on the 27th of September, having lost but one of our horses, which became exhausted and was shot. Here I learned from miners that one of my parties, in trying to raft the Tonsena River, had met with an accident, whereby the raft was wrecked and one of the men drowned. Hiring a boat from one of the miners and getting together such food as I could buy, on the 28th of September I started down the river to Taral, an Indian village, 75 miles distant, where I expected to get information that would note the whereabouts of Mr. Schrader and his party.

On the 29th I passed through Woods Canyon and effected a junction with the Schrader party. Mr. Schrader informed me that he had followed down the Copper River to a point where the coast range and that of Mount Wrangel join, where he had abandoned his horses and continued his journey by boat. Turning over to this party the food that I had brought from the mouth of the Klutena River, I proceeded on down through the Bremner Basin and camped at the head of Abercrombie Rapids just above Miles Glacier. This was the point where in 1884 I had spent three months in trying to find the Copper River Valley. There had been great changes in the fifteen years elapsing between these two visits. The Miles Glacier itself was very much emaciated, great sections of the glacier having been cut out by the water; the current, while not so violent, was still of a character to preclude any thought of navigation under any condition.

On passing Childs Glacier, I noticed that it had also receded some 500 or 600 yards, possibly more, leaving in front of it some boisterous rapids. Continuing my journey on down through the Copper River delta, I passed out into Prince William Sound, and arrived at Port Valdez on the 15th of October, having covered a little more than 800 miles on foot, horseback and by raft since August 5th.

Some five days after my arrival at Valdez the Schrader party returned, having followed up the Tasnuna River from the Copper River and, passing through the Keystone Canyon, our party reunited at Valdez with the topography of almost the entire Copper River Valley, demonstrating the existence of an all-American route from Prince William Sound to the Yukon Valley.

[*To be concluded.*]

Correspondence.

CONTROLLING THE FLOODS OF THE MISSISSIPPI.

To the Committee on Publications.

GENTLEMEN:—"Du choc des opinions jaillìt la vérité" Such was the impression when I received the May number of the *Journal of the Franklin Institute* and noted Prof. Lewis M. Haupt's answer to my remarks of December 19th, last. Graciously thanking him for the attention paid to my letter of above date, I beg to call attention to some mistakes, for which the imperfection of expressing my thoughts in a foreign language is probably responsible. Professor Haupt is positively in error when he supposes that I attempted to "apply the methods in vogue in Holland (Netherlands) for *reclamation* to those proposed in the United States for *navigation*." The strenuous efforts of the Central Service of the "Waterstaat" have, on the contrary, been to stop injurious land reclamation, and to create great navigable canals permitting the excess of flood-waters to escape easily into the sea. In these canals there is always a current, scouring the bottom and keeping it at the desired depth; the splitting into numerous small canals, when Δ-formation is allowed, was prohibited; no side canals but the river itself should bear the excess of flood-water; the river should conduct its own waters into the great herring-pond; the winter-road bed, which in summer is dry land, fertilized by the silt deposited in winter, should therefore not be encumbered by dykes, which interrupt the free flow of the water.

As for ice-dams, they did not obstruct the mouths of the rivers, but higher up they caused disastrous floods.

The tides, it is true, are an important factor in the creation of a navigable channel, but of course as far only as they are felt. Above Gorinchem (or

Gorcum) no trace of tide is perceptible; but, notwithstanding, the strenuous efforts of the Waterstaat have created a navigable channel, through which sea-going steamers can proceed with unbroken cargoes even to Cologne, in Prussia.

The absence of tides and ice facilitates, but does not change, the principles which govern the problem.

The system advocated by Professor Haupt, of outlets into side basins, as Lake Pontchartrain, Lake Borgne, is abhorred by the Waterstaat in the Netherlands, and should be much more so in a semi-tropical country like Louisiana. Stagnant pools are created, with all the attendant evils already specified in my December letter. The rivers of this colony (Java) are not yet put under such systematic control as those of our mother-country; they generally split up into numerous creeks before pouring their waters into the Java Sea; the Δs are for the greater part marshy and, consequently, sources of great unwholesomeness, as I can bear witness. Exposed for nearly four years to the miasma of the Δ of the Fji-Sadané, I sacrificed much of my health at the naval dockyard of Onrust. Where, on the contrary, as with the Solo River, the waters have been forced into the sea through one canal, without side-outlets, the strand is not unhealthful.

I cannot agree with Professor Haupt, when contending that the discharge of fresh water floods on the Holland rivers is very small, and that the tides are depended upon to maintain the depths. The basins of the Rhine, Meuse and Scheldt, although small when compared with the Mississippi, are in themselves not small. The Rhine is one of the greatest of European rivers. I regret having no figures at hand to compare its basin with that of the Mississippi. But there is no necessity for comparison, as the principles which govern the regulation of a small river are the same as those for a larger one; the works only have to be undertaken upon a relatively greater scale.

The same principles which govern the sailing of a whaleboat govern that of a large frigate. The absence of tides in our colonial rivers has not prevented the silting up of their mouths by Δ formation, as their presence in the Netherlands rivers has improved their canal-bed without the help of man. Let me add that the Yssel, which pours its waters into the Zuyderzee, an inland sea, without any perceptible rise or fall from tides, has been regulated upon the same principles, and the measures taken have been crowned with the same success as the works executed upon the other rivers.

The contention that there is no comparison as to the relative amount of sediment carried to sea ought to have been illustrated by figures; but even if there be a comparatively greater sediment carried to the sea by the Mississippi than by the Rhine, for instance, I still fail to see that other measures are justified for this one river, or that the principles which govern the sedimentation of one, have no bearing upon the other. The magnitude of the works may be influenced by such circumstances, but the principles involved, which should govern the engineer in removing the bad effect, remain the same, and are not influenced by latitude, magnitude of basin or intensity of sediment.

In his supposition that it is evident that the floods of Holland are derived mainly from the sea, Professor Haupt is quite astray from the road. For centuries sea inundations are unknown. The great inundations of 1861 and 1876, which did so much to urge the Waterstaat to hasten their work and execute

the Ferrand and v. d. Kun program, were essentially river inundations; the first one complicated by ice encumbrances; the inundated land, in the first named year, the Bommeler and the Fielerwaard, and in the second, the Bossche-veld, are above sea level, above tide influence even, and could not be inundated by the sea. All argumentation, based upon the erroneous supposition of the character of the floods, is consequently void of interest; it has, therefore, never been aimed to "dam the floods from the sea," but, on the contrary, to create as easy a way as possible towards the sea, by removing sand bars and other encumbrances, as dykes, etc., in the winter bed, by short cuts, by a broad mouth, and all those means advocated by Ferrand and v. d. Kun, and enumerated in my December letter (page 384). The works involved to carry out the program of these engineers are, however, heavy and expensive, and decade after decade has seen their systematic execution; but although far from finished, even in the unfinished state, they have, nevertheless, prevented the occurrence of disastrous floods in the last quarter century.

The damming up of the old Maas mouth near the Hoek of Holland is quite misunderstood; it was in order to replace the old crooked and narrow Brielsche gat, as it was called, by a new, straight and broad one of sufficient capacity to carry the waters of the Rhine into sea.

The destination of the Catwyk canal is also quite misrepresented by Professor Haupt. I did not write that it should "discharge its"—that is to say, the Rhine's—"superfluous water into the North Sea," but "to secure the *Waterschap of Rynland* ready means of discharging its superfluous water," etc. This makes a great difference; not a drop of the Rhine's waters is delivered into the sea by the Catwyk Canal. For centuries the Rhine did not deliver its waters through its old roadbed, along Utrecht, Woerden and Leyden into the sea; a sluice near Wyk by Duurstede prevented this delivery through its old roadbed, which, as before said, was smothered in the downs near Catwyk: its waters took partly the bed of the Lek, partly that of the Waal, and afterwards of the Maas. (Krayenhof had proposed to canalize the Lek and to retain only the Waal, sufficiently enlarged, to carry the Rhine waters into the Maas. It was quite rational to propose this, and quite in the line of his principle to minimize the splitting into smaller canals of a great river; and but for the great cost involved it would have been carried out.)

The rainfall of the waterschap of Woerden and of Rynland had to be carried into the sea, and *one* of the means to realize this was the digging of the Catwyk canal through the downs, with sluices to prevent inundation from the sea into the Waterschap of Rynland, when the sea level is higher than that of Rynland's boezem (bosom), that is to say, above the level of the canal, which collects the waters which the several polders throw into it, for subsequent carriage into the sea.

I hope in the above to have demonstrated that Professor Haupt has involuntarily quite misunderstood my meaning; that is to say, that the Waters aat in the Netherlands did not intend to dam the rivers against intrusion of the sea; but, on the contrary, to open the rivers as much as possible for the delivery of the flood waters, regulating them, and, at the same time, individualizing them. The Waterstaat's work has been largely to remedy the unsystematic work of centuries—the uncontrolled impoldering by dykes of

the sediments of the rivers If Professor Haupt will only review what I have said before, and take into account the explanations of my present letter, I think he will be aware that we agree in almost the whole matter, with the exception of one point only, but a very especial one; that is to say, that of the creation of side outlets, and the allowing of Δ formation.

Whether the learned professor be wrong or not, I beg to illustrate by another example—the regulation of the mouth of the Danube, which was based upon the same principles as that of the Rhine and other rivers in the Netherlands; the exceptions taken against my referring to the success with these rivers cannot hold good in the case of the Danube; the Black Sea is without tides, and the sub-tropical climate of Bessarabia is a warrant against ice obstructions.

I have now come to the most difficult part of my answer—discussing the facts related by Professor Haupt about the work done in the Mississippi mouth. To discuss them in detail would not only intrude upon the space

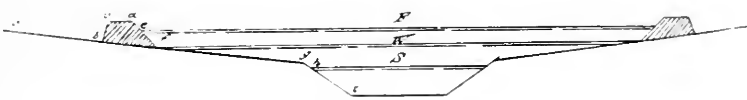


FIG. 1.

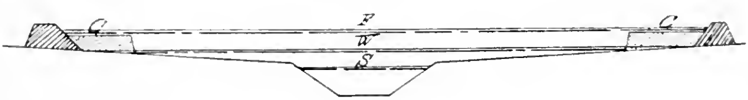


FIG. 2.

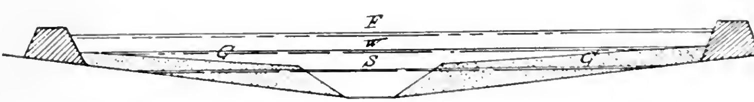


FIG. 3.

allowed for a discussion, but is, besides, impossible from the circumstance that the available data are insufficient for me to discuss them thoroughly. I cannot sound farther than my line goes, and can, therefore, only adhere to vague generalizations. There is, however, sufficient material available to convince me that in the engineering of the Mississippi mouth grave faults have been committed. The Waterstaat has always insisted upon the creation and maintenance of a distinct summer-, winter- and flood-bed. Let, in *Fig. 1*, *S*, for instance, represent the summer, *W* the winter, and *F* the highest known flood level; the space between *f* and *g* should remain undisturbed by dykes; no building should be allowed in this region. Farmers and cultivators have always a tendency to create quays (zomerkaden) near *g* to defend their property against the invading winter floods, but these should not be allowed. If the natural slope of the ground is less than in the former case, cribs should be created as at *C*, *Fig. 2*, in order to limit the river to its channel. If the river banks slope into the bottom of the river, cribs extending from summer level to winter level should define the summer and winter road beds. As a rule,

riparian land-owners are allowed to build these cribs, and the reclaimed land is the property of the builders. If the Government builds them, it becomes the proprietor. If the banks are high and above flood level, as in *Fig. 4*, then excavation and dredging must assist the regulation work.

If, in these and in similar ways, appropriate winter- and summer-beds have been created, the régime of the river is such that it will maintain its depth without dredging or further assistance of man. In summer, when the discharge of water is small, the narrow bed will carry the water with sufficient depth to allow navigation ; sufficient strength of current will be maintained to scour the bottom. In summer the water is always clearer than in winter, and the winter sediment will be scoured in summer. In winter, when the water is muddy, the river will deposit the greater part of its sediment upon the berms *fg* (*Fig. 1*), the current there being weaker than in the deep central channel. The fertilized berms will yield good crops in summer time. The

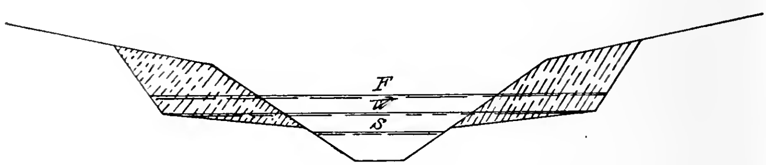


FIG. 4.

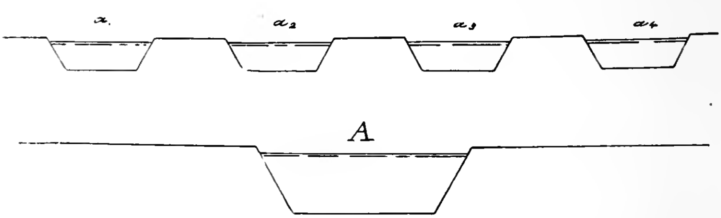


FIG. 5.

first rains will scour much of the deposited silt into the central channel, which will carry it into the sea. These berms are the secret of success. They protect the inner banks against inundation, and the central channel against silting up. From the illustrations accompanying Professor Haupt's original article in the October number of the *Journal*, 1903, I infer that the Mississippi banks are not systematically provided with such berms, and, if existing, the crevasses of 1903 on Bayou Lafourche prove that they are protected by dykes, which, as has been demonstrated, spoil the good work they should do, and, therefore, should strenuously be prohibited.

Another grave fault Professor Haupt's letter of March indicates, is the narrowing of the roadbed towards the end ; on the contrary, the channel should gradually widen. With such faults I am not at all astonished that the Mississippi River Commission reports in 1903 that "to permanently locate and deepen the channel, has not been practicable under existing conditions." No better proof is necessary of my contention that your engineers are on the

wrong trail with the improvement works at the Father of Waters, than this clear confession.

There was one on the right track, the unsurpassed Eads. If his course had been followed I am sure the above words would have remained unwritten. But from what Professor Haupt says about the works executed at the South Pass, it is clear that the great man's work has been badly spoiled. It belonged to Eads' system to have only one outlet for the great river, exactly as it is aimed by the Waterstaat for the Rhine and other great rivers. Now it is ridiculous to contract such an outlet to a width of 600 feet for a river like the Mississippi! That other passes needed to be opened after the spoiling of the South Pass is as clear as daylight; the one fault engenders another.

Professor Haupt quotes the words of the *Enc. Brit.* (Holland, page 65). No better quotation could be resorted to than this to prove the beneficent character of the works of the Waterstaat. As I have already sketched out, before the French Revolution there was no central control over the rivers; the first propositions originated with Krayenhof; the first decades of the nineteenth century passed in deliberations and preparations; the latter decades in the vigorous taking in hand of the works. And now be pleased to look at the frequency of the floods before and after the systematic control of the rivers; 1876, not quoted by the *Enc. Brit.*, is the last flood year. In the last quarter of the eighteenth century no less than four great floods are recorded; during the whole of the nineteenth century not more than the same number are on record! Indeed, the quotation from the *Enc. Brit.* speaks volumes.

In concluding I beg to ask, What does the reader prefer: to split the mouth of a river into, let us say, four small creeks, like a_1 to a_4 in *Fig. 5*, or to concentrate the flow into one great channel A, of the same capacity as the four creeks together? Are not the greater depth and breadth of A essential advantages? Cannot larger and more seaworthy ships pass the channel A than the small creeks? Is not the proportion of channel-capacity with rubbing surface much more favorable with the large channel? Is not the friction much less with this than with the small creeks? Does not therefore the large channel alone afford a much freer outlet for floodwater than the four small creeks combined?

Professor Haupt derives an argument for the opening of the outlets of Cubitt's Gap and Jump from the cheap land reclamation; but this argument is irrelevant, as we are not considering land reclamation, but controlling of floods. Further, I cannot reconcile his contention that "the creation of a free discharge near the mouth to avoid the floods rapidly, would not injure the works of Captain Eads," with his previous remark, that the South Pass is fouling at the rate of 5 inches per annum. Really all Professor Haupt's remarks confirm me in the opinion that the Waterstaat is right when adhering to the canon that a river should depend upon its own roadbed to discharge its waters, and not upon side-way tappings, which should act as safety-valves. The less a steam-boiler blows off, the better its régime; constant or periodical blowing off of the safety-valves means a bad régime: a main steam-pipe unproportioned to the boiler capacity.

Let, therefore, the Mississippi Commission beware of the faults committed by our ancestors; a great river is not governed by small means; outlets, levées and such like measures are to be classed under the head of small

means, palliatives, half-measures. The Waterstaat engineers have attacked the problem of controlling the floods and thereby creating navigable channels in grand style; "aux grands mots les grands remèdes" has been the device which guided their actions; mutually they were in perfect harmony in the appreciation of the general character of the measures, and although in the execution, without a doubt some friction has occurred, there was unity in aim; the one did not spoil the work of his predecessor; a great end was aimed at, which was splendidly achieved. After 1876 nothing more is heard of disastrous floods in the Netherlands; the last on record in the Mississippi is that of 1903. In other words, the floods in the Netherlands have been controlled; those of the Mississippi not yet.

Finally, I beg again to thank Professor Haupt for referring to me as "distinguished." He does me more honor than I expected or deserve; not less gratified I was with his addressing me as a friend, which I beg to reciprocate; and in thus taking leave of him, it is only in the hope that we will meet again in defending the Father of Waters against floods and sedimentation!

Respectfully yours,

H. VAN MEERTEN.

Member of the Institute.

BUITENZORG, JAVA, June 16, 1904.

Notes and Comments.

RECENT ELECTRO-CHEMICAL DEVELOPMENTS.

Two patents granted on May 17th to Mr. Alfred H. Cowles, of Cleveland, refer to methods of manufacturing calcium carbide. There is nothing new of a fundamental nature in his method since the carbide is produced simply by heating a mixture of lime and carbon to a high temperature. The patents refer rather to details of the method. Mr. Cowles intends to make the operation continuous and superheats the carbide so that it may be easily tapped off.

A patent granted to Mr. R. N. Pelton, of Detroit, Mich., refers to an electric furnace for dentists. Its essential part is a muffle with a heating coil of platinum wire in the wall. The outside of the muffle is surrounded by another heating coil.

Mr. P. J. Boucher, of Cleveland, Ohio, patents an apparatus for purifying water by electrolysis with the aid of aluminum electrodes. As well known, a flocculent hydrate is thereby produced, which coagulates the various impurities and allows them to be easily removed from the liquid by settling or filtering. If the current always goes in the same direction, deposits form on the electrodes and interfere with their action, and the electrodes unequally deteriorate. To counteract this tendency, the inventor automatically reverses the current at predetermined periods of time. He also provides means for automatically relieving the pressure of the gases evolved by electrolysis and for insuring the current being turned on or off whenever the liquid is turned on or off.

A patent granted to Mr. F. Hinz, of Berlin, Germany, refers to a process of manufacturing peroxides of magnesium and zinc in a diaphragm cell. For making magnesium peroxide he uses an aqueous solution of magnesium chloride in the anode compartment and a neutral solution of magnesium chloride and hydrogen peroxide in the cathode compartment. Magnesium deposited on the cathode by the action of the current reacts with the hydrogen peroxide and yields magnesium peroxide.—*Electrical World.*

WIND-MILL FOR ELECTRIC POWER.

Harnessing the wind to generate electricity for farm use is no longer a novelty. The first of these wind-mills were used experimentally to generate electricity for lighting houses and barns; success has since stimulated attempts to use them for more ambitious projects. To-day a good many are being run to generate power to operate small motors. The use of wind-mill power for generating electricity was tried successfully two years ago in Europe, and now at Hamburg and Leipsic are electrical plants which derive their motive power entirely from the wind. The wind-mills are strongly built, and are designed to take the wind at any angle. The regulation of the motor is effected by an automatic switch, which cuts out the battery when the wind falls to a low pressure.—*Iron Age.*

THE POSSIBLE UTILITY OF THE SUN SPOTS.

Sir Norman Lockyer, the British astronomer, has advanced a remarkable new theory concerning the utility of sun spots. Our knowledge of sun spots is distinctly limited, and Sir Norman Lockyer contends that the discovery and understanding of these phenomena will prove one of the most beneficial additions to the world in general. He advances the theory that such knowledge may enable astronomers to convert the sun into an agent to enable us to cope with droughts and famines, and that the spots on the sun may render it possible to predict with practical certainty the coming of famine and the exact part of the world where it will take place.—*Scientific American.*

COAL IN NEVADA.

On account of the scarcity and high price of all fuel, the occurrence of coal, even of inferior quality, within the desert region of Nevada, is a matter of great interest. At the north end of the Silver Peak Range, in Esmeralda County, just south of the road between Silver Peak and Candelaria, coal beds occur in Tertiary formations. These beds have been recently visited by Mr. J. E. Spurr, of the United States Geological Survey, who has described them in a paper published in Bulletin No. 225, which is entitled "Contributions to Economic Geology, 1903."

This coal is said to have been discovered by William Grozenger, of Candelaria, in 1893, and the seams are now continuously located. The chief seams are four in number and some of them extend for a distance of 3,000 or 4,000 feet in outcrops that trend in a northwesterly and southeasterly direction. Mr. Grozenger has classified the veins, counting from the top, as the first,

second, third, and fourth veins. The distance between the first and second veins perpendicularly is estimated by him to be 150 feet, between the second and third, 70 feet, and between the third and fourth, 130 feet. The uppermost vein, No. 1, seems to be relatively poor and small, and, as exposed in outcrop, of little value. Vein No. 2 is in coal shales and is several feet thick. The vein contains considerable slate parting or bone. Vein No. 3, which is also in the coal shale, is of better quality and thicker than No. 2. No. 4 shows 6 to 8 feet of coal of much better quality than the upper veins. Some of this coal has a brilliant lustre, while the coal of the other veins is dull in color. It is used as a forge coal by Mr. Grozenger and affords a coke. The coal contains a smaller per cent. of ash than that of the upper veins.

These prospects have been bonded several times. The chief prospecting has been on the upper veins, and the coal developed has been so light in nature and so full of ash that prospecting has been repeatedly abandoned. It seems, however, that the lowest vein has been somewhat neglected and possibly this may be found in the future to be available as fuel. The outcrop of this vein is limited and broken near the fault, but its underground extent must be great. Inasmuch as the beds underlying this seam are not exposed on account of the fault, it is not impossible that still other seams may occur beneath it.

The numerous mining enterprises which have been recently developed in this region, where there is no water power, little wood supply, and only expensive transportation, make even these coals, which are undoubtedly poor in quality, important. Since they all contain a large percentage of volatile matter, the gas in them might be separated and profitably used for fuel.

EFFICIENCY OF THE NERNST LAMP.

L. R. Ingersoll has redetermined the efficiency of the Nernst lamp by Angström's method, in which the total spectrum of the light is dispersed in order to separate out the visible spectrum, and the visible rays are then recombined by means of a cylindrical lens and thrown upon a bolometer or thermopile. The glowers were burnt freely in air, without heaters, on a 100-volt alternating current. A voltmeter and wattmeter across the terminals of the glowers and a rheostat in series enabled the author to keep the voltage or power consumption constant at any desired value. The principal factors in the determination of the efficiency of any glower are its age and the power it consumes. The experiments showed that Nernst glowers are by no means uniform. New glowers show an efficiency of from 4·35 to 4·70 per cent. The efficiency falls rapidly for about the first twenty hours, decreasing to a mean of 4·3 per cent. and varies only slowly after this. Tests of glowers of forty hours' age and upward gave a mean efficiency of 4·17 per cent. Some very old glowers gave only 3·6 per cent. It is noticeable that after a glower has been burned upward of twenty hours it develops a marked crystalline appearance, and it is probable that the fall in efficiency is due to the greater radiating surface and consequent lower temperature afforded by the crystalline structure. The author adds that if, as is now proposed, the glowers are aged before they are sent out, the deterioration with time may no longer be observable. As regards Hartman's observation, that old glowers show an increase in luminous intensity, the author points out that Hartman kept the current

constant rather than the power consumption. As the resistance of the glower increases with age, a constant current means an increased power consumption, and hence a greater emission.—*L. R. Ingersoll, Physical Review, November, 1903.*

DISTILLATION OF METALS.

Experiments carried out by Moissan and O'Farrelley, with the aid of the electric furnace, show that the usual laws of distillation apply as well to the distillation of mixtures of metals (*Comptes Rendus*, 1904, p. 1659). Various mixtures were heated in the furnace for different times, and the residues were analyzed. In the case of copper and zinc and copper and cadmium, the zinc and cadmium were completely expelled after short periods of distillation. In the case of copper and lead, the same result was reached, though only after longer distillation, during which the percentage of lead gradually lessened. In the case of copper and tin, some mixtures gradually increased in copper content, some in tin content, and others distilled without change of composition. With mixtures of lead and tin, the lead gradually decreased until pure tin remained. A remarkable character of tin is the wide range of temperature through which the metal remains liquid; while it melts at 226° C., its boiling point is above that of copper and lead.—*Iron Age.*

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, September 21, 1904.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 21, 1904.

PRESIDENT JOHN BIRKINBINE in the chair.

Present, 86 members and visitors.

Additions to membership since last meeting, 35.

The major portion of the evening was given up to a discussion of the question of "The Use of Copper Sulphate as a Germicide for the Purification of Potable Water," with particular reference to the applicability of the process to the local water supply.

The discussion was opened by Dr. Hobart A. Hare, of the Jefferson Medical College, who, after referring to the experiments made by Drs. Moore and Kellerman, of the U. S. Department of Agriculture, which indicated that very small additions of copper salts to drinking water sufficed to destroy the vitality of typhoid bacilli, stated that similar experiments made in the bacteriological laboratory of the Bureau of Health by Drs. A. H. Stewart and Mary E. Pennington, had not only confirmed the results of the Washington experts, but had also demonstrated that the presence of one part of copper in 4,000,000 of water was sufficient to destroy all typhoid germs in three hours, a solution forty times weaker than that indicated as efficient for the purpose by the Washington experiments

Dr. W. J. Williams, chemist to the Frankford Arsenal, admitted the efficiency of copper as a germicide, but held that its value from the standpoint of

public health would depend entirely on the care and intelligence with which it was applied in practice.

Mr. John C. Trautwine, late Chief of the Philadelphia Water Department, presented some data collected by Prof. Robert Fletcher, of Dartmouth College, Hanover, N. H., relative to the use of copper sulphate for treating the public water supply of that town to destroy and check the growth of offensive algae, with which it was contaminated. The introduction of one part of copper sulphate to 4,000,000 parts of water, trailed through the reservoir in a bag, not only effected the total destruction of the objectionable organisms at the end of sixty hours, but also so effectually purified the contents of the reservoir that, at the end of ten weeks, the water exhibited no recurrence of the pollution.

Drs. Stewart and Pennington, of the bacteriological laboratory of the Bureau of Health, gave an account of their experiments, above referred to.

Mr. John W. Hill, Chief of the Bureau of Filtration, at the invitation of the President, gave his views of the subject. Mr. Hill affirmed his confidence in the efficiency of thorough filtration, and instanced the results obtained at the Roxborough and Belmont filter plants. where from 97½ to over 99 per cent. of the bacteria present in the raw water were shown to be destroyed. He objected to the use of copper salts for this purpose, first, on the score that its application would be costly; and, second, for the reason that the use of any chemical method of purification was objectionable, on general principles.

Remarks on the subject were also made by Prof. C. B. Cochran, Dr. G. H. Meeker, Medico-Chirurgical College, Philadelphia; Dr. G. Goldsmith, and Messrs. P. A. Maignen, Wm. L. Dubois and Reuben Harries.

Dr. Edward Martin, Chief of the Bureau of Health, in closing the debate, claimed that the value of copper as a germicide had been fully demonstrated, and while not denying the value of the costly filtration system now in course of completion for the betterment of Philadelphia's water supply, referred to the fact that this important work would not be completed for several years, and inquired if in the meantime our citizens should not be given the benefit of the copper germicide treatment, by which doubtless many lives would be saved which otherwise would fall a sacrifice to typhoid fever.

The Chairman expressed the thanks of the meeting to the contributors to the discussion.

Mr. Walter Zimmerman, of Philadelphia, Vice-President of the American Federation of Photographic Societies, presented, in brief, a plan for the collection of historic photographs in all parts of the United States, in which the co operation of the Franklin Institute is solicited.

On the Secretary's motion, duly seconded, the following resolution was adopted:

Resolved, That the proposition of Mr. Walter Zimmerman on behalf of the American Federation of Photographic Societies, be referred to the Section of Photography and Microscopy with a favorable recommendation, and the further recommendation that Mr. Zimmerman be requested by the section to serve as a member of any committee which it may appoint to give consideration to the subject.

Adjourned.

WM. H. WAHL,
Secretary.

JOURNAL

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Discussion on the Individual Operation of Machine Tools by Electric Motors.

Before the Franklin Institute, February 17, 1904.

OPENING REMARKS BY CHARLES DAY.

I will not attempt to treat fully the subject under consideration, namely, the "Individual Operation of Machine Tools by Electric Motors," but rather present the matter in a way to facilitate discussion by those present.

The first application of the motor in workshops was probably in 1883, or only twenty years ago. It was estimated in January, 1903, that in the United States alone the motors operating in manufacturing establishments would aggregate at least 350,000 horse-power, and this figure has grown so rapidly since that time that any estimate I might make would probably be wide of the mark. These figures, however, will clearly indicate the recent development and tremendous growth in this field, and it would seem well, after three years, to again bring the subject before this body for discussion.

A paper on the "Motor Drive," by Mr. Daniel Adamson, presented March 14, 1896, before the Manchester Association of Engineers, one on "Electricity *versus* Shafting in the Machine-Shop," by Charles H. Benjamin, read at the Hartford meeting of the A. S. M. E., in May, 1897, and the discussion held here in January, 1901, all arrived at the same general conclusions, and only differ in the descriptions of types of apparatus.

A paragraph from Professor Benjamin's paper, written nearly seven years ago, is most interesting, as one constantly reads the same conclusions in the technical papers of to-day:

"The writer, as a mechanical and not an electrical engineer, hesitates to say much on this delicate subject. However, it is a question which must be settled at the outset in deciding upon the arrangement of a shop.

"The great advantages of the polyphase or induction motors are in their simplicity, their freedom from rubbing contacts and the constancy of their speed; the great disadvantage, the fact that the speed cannot be regulated.

"When electricity is to be applied simply to run line-shafting and counters, and the speed of separate machines is to be controlled by the usual belts and gears, the polyphase system is entirely satisfactory. On the other hand, when it is necessary to use independent and direct-connected motors on cranes and on machine tools, prompt and economical speed control is an absolute necessity; and it is here that the continuous-current machine has a great advantage. Without any prejudice, it is the earnest belief of the writer that the greatest advantage in electrical transmission is to come from the use of independent motors to the largest extent possible, and that the time will come when nearly every machine in the shop will have its own motor. Progress in this direction is slow, and the intermediate steps must be taken first; but when an electrician sneers at the use of direct-connected motors, one cannot but suspect that it is only because he has not yet perfected a motor that will satisfy the requirements."

When this was written motors were rarely directly connected to machines, and most machine-tool builders con-

demned the practice, while to-day several of the largest manufacturers of engine lathes have informed us that 30 per cent. of their product is designed for their use.

It is not surprising that the electrical engineer, who is familiar with the great improvements made in this apparatus, should clearly see the desirability of the motor drive; but to shop managers, not familiar with recent progress, the savings to accrue after the expenditures necessitated, are not assured. The man who analyzes the problem from the standpoint of earnings to be effected, and is not willing to spend money unless reasonably sure of an adequate return, finds nothing satisfactory in such statements as better crane service, ease of handling, proper location of machines, etc.

A number of papers have been written, however, since the last discussion here that throw light on the subject from other sides, and such work will surely do much to hasten the more general adoption of the individual drive. I refer to the detailed analysis of the problem from the standpoint of machine-shop requirements rather than the constant repetition of generalities, which mean nothing unless the means are available to make possible their fulfilment.

Such factors as independent location of machines and better facilities for handling work are interesting, but are they worth while? In other words, is the constant-speed individual motor drive a paying investment? Ease of handling and speed control are terms that one constantly hears; but is the additional expenditure necessary to obtain them justified from a consideration of dollars and cents? Some concerns have gone ahead blindly, simply accepting the statement that the individual drive is the proper thing, and in almost every instance the resulting equipments do not begin to possess the possibilities that they should, and in many cases are not yielding a return to justify the expenditure.

Until it is fully understood that the words "a motor-driven tool" need not necessarily imply high efficiency, the advantages made possible by the use of the best types of such apparatus will not be gained. I feel that I cannot dwell too long or forcibly on this point. The tool steel, the

machine, the motor, the man, are all but means to an end. Let us always first bear in mind this end. Machinery designed to fulfil the conditions of economical production is the machinery that will be purchased, not only once, but repeatedly, and that is what is needed to perpetuate this work. We can all point to large motor-driven equipments —usually the first installed; will they be duplicated or extended? Only if it can be clearly shown that a proper return has resulted. As stated above, a number of the largest equipments do not possess the possibilities anticipated; in others they may be present but of no earning value, on account of lack of intelligent direction of work. This is equally true of belt-driven machines; but the motor drive, with its greater possibilities, should only be adopted as the result of a definite need.

The shop manager who does not see clearly the inability of a belted tool to attain maximum output, and the reasons, cannot hope to gain appreciably by purchasing a motor. Let me repeat, a motor-driven shop does not insure low cost of production any more than efficient guns can guarantee a naval victory.

The intelligent direction of work involves many more factors than most shop men realize, and hence we find success of the same degree, as far as earning power is concerned, resulting from innumerable causes. The plant with the most modern equipment may not profit by it to an appreciable extent, but nevertheless pay large dividends because the selling organization is under the direction of one possessing an exceptionally keen insight into the motives of prospective purchasers.

I may seem to digress from the subject at issue, but I want this meeting to stand apart from all others in that the motor drive be considered from the standpoint of a money earner. The time has arrived when it would be much better to close one's eyes and grasp any one of possibly four makes of apparatus, devoting the time to its proper installation and operation, rather than reversing the process, as is so often done.

The manufacturer of electrical apparatus for machine-tool

driving, who is desirous of obtaining the greatest success, must not only make efficient motors and controllers, but see that they are *properly installed and their use understood.* An electric generator or steam engine may be heavily overloaded and break down, but this may be no discredit nor harmful to the reputation of the maker, for it is usually an easy matter to locate the trouble. The *earning power* of such an installation is largely dependent upon the design and workmanship—features that can be passed upon before the machinery leaves the works. If the power plant is found to be too small, more units can be readily added without in any way interfering with those in use. Consequently, these two classes of work present distinctly different problems to the engineer.

In many instances the individual drive is justified by greater facility in handling material, made possible by operating cranes over the tools. This return is dependent only upon the absence of overhead work, and is not affected by size or type of motor. The great advantages claimed for the direct-current, variable-speed motor, however, are based upon the saving effected on the operator's time which, in turn, depends upon his ability to run his machine at all times to its full capacity, or rather machine each piece of work as rapidly as its character will permit.

Concerns that market motors to fulfil certain conditions on the armature shaft, requiring the customers to decide whether these conditions are right or wrong for their needs, are sure, as time goes on, to find many of them dissatisfied. The electrical companies pride themselves upon the efficiency of their apparatus, but frequently the purchasers, through improper selection of sizes and types, are anything but pleased, being unable to reap the return that they understood was sure to accompany a motor-driven equipment.

It is claimed, and rightly, too, that the enormous amount of detail work required to do justice to the engineering features, in connection with the adaptation of motors to machine tools, cannot be handled without an additional charge. To do this work superficially is in many cases more harmful than not to do it at all.

I do not intend to take up your time now with details, but will say that after equipping over 100 machines of different types and sizes, we are prepared to speak with confidence as to the cost of such work. To make the necessary study of requirements, and work up complete shop drawings for all parts needed, averages in flat cost $150 per machine. Unless handled in this way the shop cost is sure to be excessively high.

If the average shop manager had the information at his disposal, and the time and facilities to enable him to properly equip such old machines as would justify it and intelligently purchase new ones, the problem would be a comparatively simple one. This is true in some establishments—machine-tool builders for example; but we cannot expect those in charge of large repair shops for railroads, collieries and other industries to have either the time or experience to conduct this work properly. Considering the rapid development in this field, much work already completed has been handled as creditably as could be expected; but, at the present time, nearly all the principal electrical companies are giving much thought to this subject that they may meet the requirements of their customers to the best advantage.

Progress is clearly shown in the accompanying illustrations. *Fig. 1*, illustrates a New Haven engine lathe equipped about twelve years ago in accord with drawings furnished by the Crocker-Wheeler Company, which purchased it for their own use. Some explanation will be needed, as the lathe has been modified, if I remember correctly, from the original design. The arms shown on the front of the headstock originally operated rheostats, a certain amount of speed control being obtained by armature resistance. This method being found unsatisfactory, the motor was run at constant speed, the necessary spindle speeds being obtained by the nest of gears which fill the space originally provided for the resistance coils. This equipment, notwithstanding its crude character, made it possible to operate a crane over the machine and, if the motor had been large enough, would have possessed practically all the advantages of the present induction-motor system.

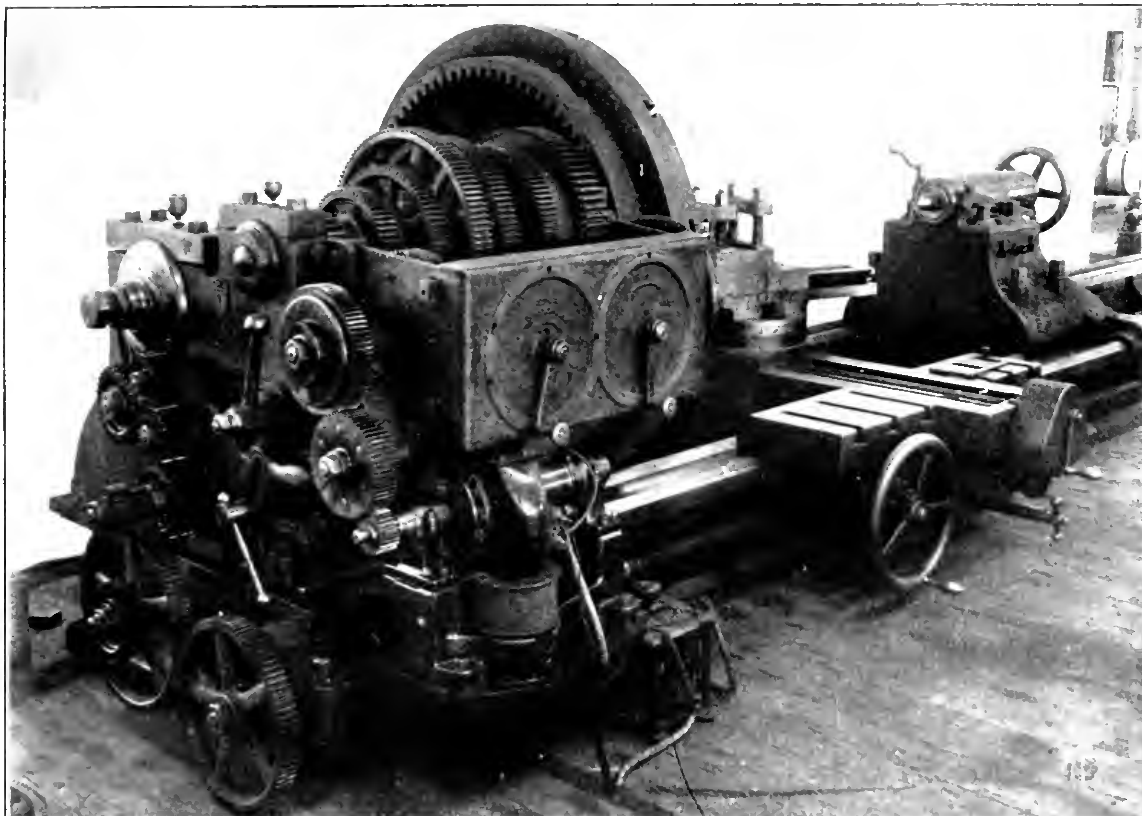


FIG. 1.—One of the first motor-driven engine lathes equipped by the Crocker-Wheeler Company for their own use.

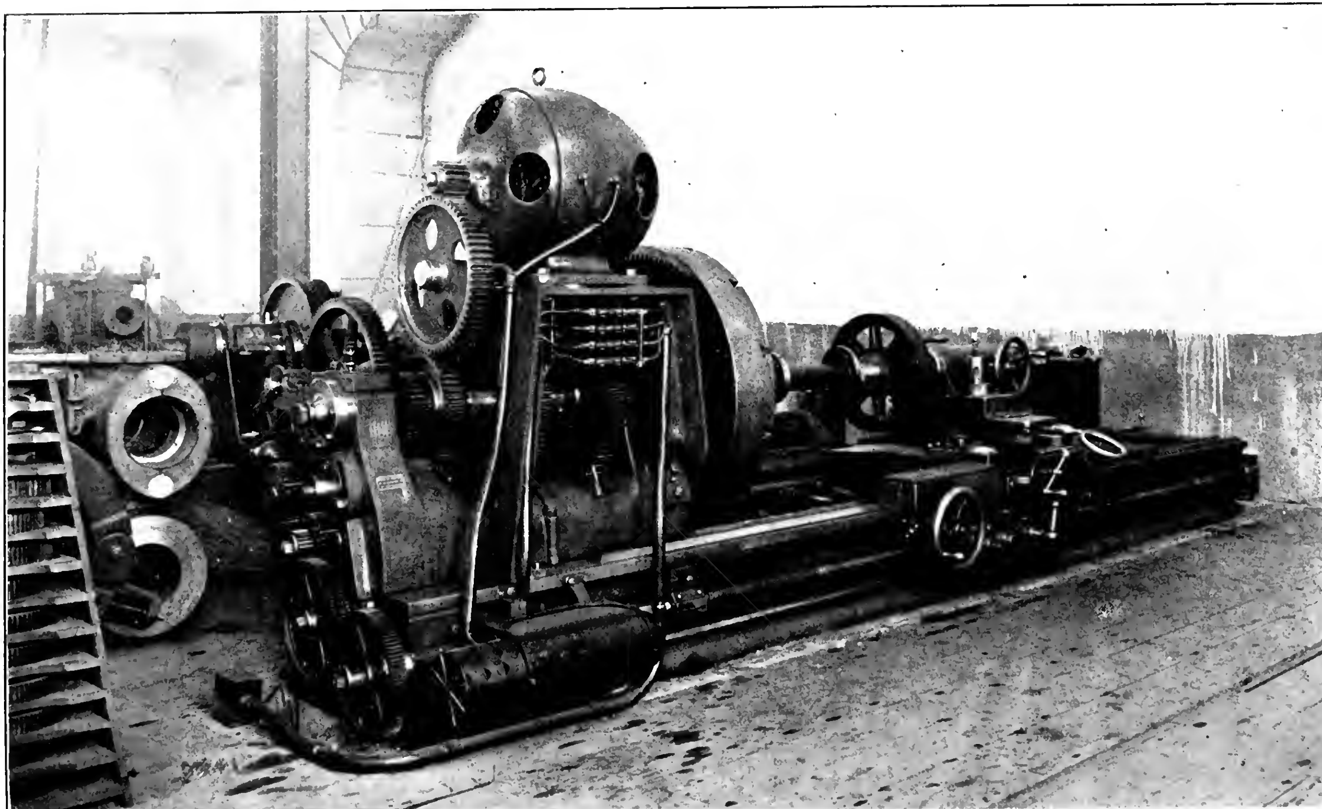


Fig. 2.—50-inch Pittsburg lathe, arranged for motor driving by Dodge & Day (Crocker-Wheeler multi-voltage apparatus).

Compare with it *Fig. 2*—a 50-inch Pittsburg lathe designed for belt drive, but now equipped with apparatus also manufactured by the Crocker-Wheeler Company. We have engineered the equipment of a number of large engine lathes which might appeal to the eye much more than this one as being more symmetrical, etc. I chose it, however, on account of its rugged character and the increased output made possible by the change. Practically all the original driving gears were replaced by new ones of greater strength, and the ratios changed so that with the range in motor speeds obtainable a uniform increase in speeds would result. It is not necessary to dwell upon the good features of this equipment, as most of you are familiar with them. The ease of handling secured by the operation of the controller from the apron, where at all times the operator has the machine under perfect control, adequate power for any work that the machine is adapted for, simplicity of the entire arrangement, so that a workman of ordinary intelligence can grasp, in a few moments, the method of operation, are the points which suggest themselves at once. Unfortunately, we have no statistics showing to what an extent the possibilities of this tool have been increased, but experience would indicate that, under average working conditions, metal could be removed at least twice as fast as was originally possible. We prefer to be rather conservative in making such estimates, but I can speak with confidence on this point, as the matter has recently been strikingly brought to my notice in the shops of one of our clients where we have similar machines running side by side, one being operated by belt and the other by motor. The belt-driven machine has every advantage which we could give it. A special countershaft was designed with tight and loose pulley in place of the ordinary friction clutch ; the belts all kept at a proper tension and so designed that the cone belt would be the first one to fail. The ordinary method of lubricating the spindle, which so often gives trouble when doing high-speed work, was replaced by a special arrangement which we have found very satisfactory. The motor-driven tool was equipped with a Bullock multiple-voltage motor, the

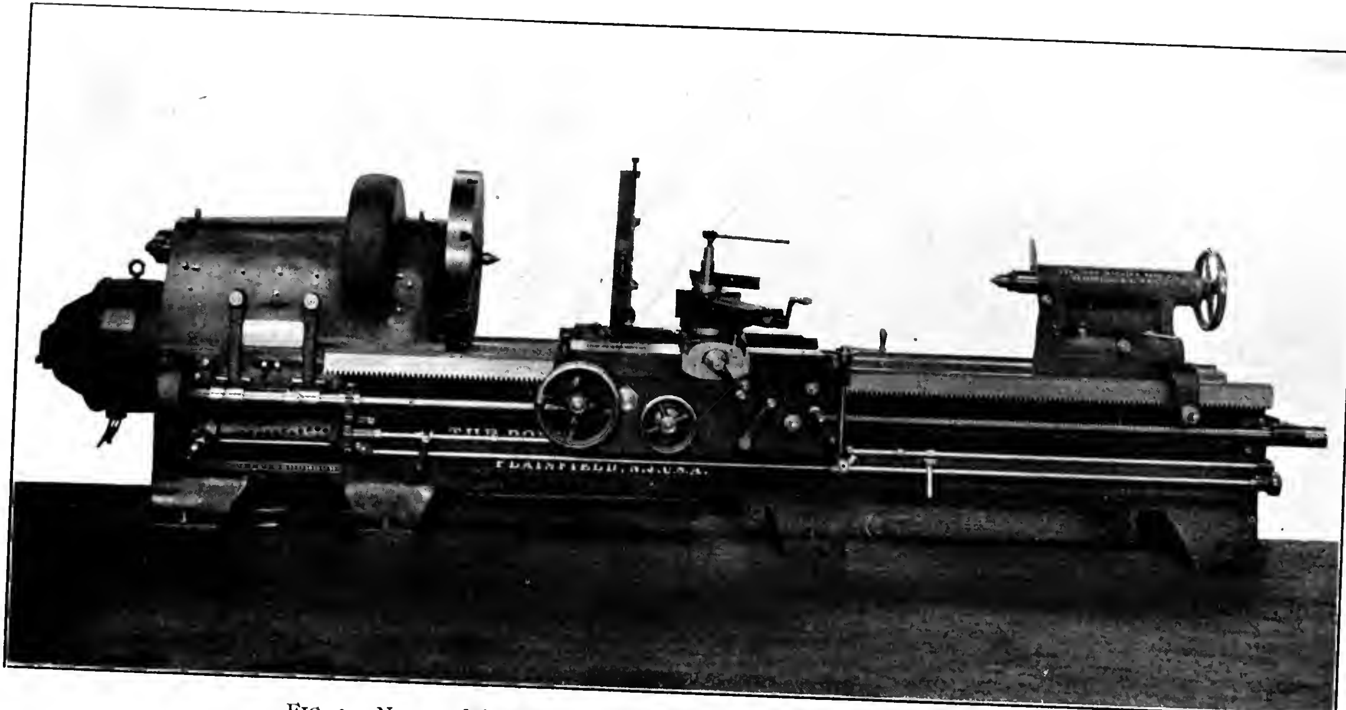


FIG. 3.—New model Pond lathe equipped with Westinghouse type S motor.

general character of the equipment being similar to the one just illustrated. The job in hand at the time referred to consisted in the roughing of shaft journals, the conditions arrived at on the motor-driven machine representing the full capacity of the cutting tool. On the belt driven tool it was not possible to use more than one-half the feed, and even then the belt slipped badly. It is, of course, a comparatively simple matter to figure this problem out. Those in close touch with machine-tool design know that in the average machine power is usually sacrificed to obtain a sufficient number of speeds on the step cone, but to see the two machines side by side, working under the most favorable conditions on the same work, tells the story more clearly and forcibly than is possible in any other way. Of course the best results will only be reached when machine tools are *primarily designed* to take advantage of every known means toward the attainment of economical production. Such an equipment is illustrated in *Fig. 3*, being a Pond lathe equipped with a Westinghouse type S motor.

Actual figures showing earnings effected are what are needed to-day, and such information as the comparative costs of individual and group drives in the Collingwood Shops of the Lake Shore & Michigan Southern Railroad is of great value. The conclusion is reached that if the machine-tool builders can market machines suited for motor driving at the same price as the belt-driven type, it is as cheap to equip all large machines with individual motors as to drive them from line shafting. It has also been shown that the average yearly expense of operating these tools with variable-speed motors is $1,725.70, while it would be $1,687.10 if the constant-speed type were adopted. These figures are based on a liberal rate of interest and depreciation, and those who wish to refer to them can find all the data in the report of June, 1903, of the Committee on Electrically Driven Shops, appointed by the American Railway Master Mechanics' Association. The committee state that as the difference in operating cost between variable-speed and constant-speed motors is but 2¼ per cent., it is only necessary to obtain an increased output of this amount to

justify using the variable-speed type. This conclusion does not hold in actual practice. The substitution of the variable-speed for the constant-speed motor does not bring in $2\frac{1}{4}$ per cent. more work, nor does it make it possible to dispose of any equipment, so the saving of $38.60 must be made on the labor item only. As the latter was $840, an increase in output of at least $4\frac{1}{2}$ per cent. should result. If, on the other hand, the proportion of the man's time had been a smaller item, a proportionately greater reduction in time would have been necessary. It is not my desire, however, to criticise this data, for I feel that it is just such investigations that are most needed at the present time. This analysis shows the economy that must be effected to justify the use of the variable-speed motors, but no attempt was made to analyze the problem from the other side; namely, to see what saving actually should occur after the installation of the apparatus.

Mr. R. W. Stovel, when working on the equipment for the Pittsburg & Lake Erie Railroad, obtained some interesting data in this connection, his conclusions being as follows:

"It is to the advantage of any machine shop to put an individual motor on a 16-inch lathe, provided this tool is busy throughout the shop year; that is, keeps one man busy all the time on a variety of work. It is advantageous to put an individual motor on all variable-speed tools which are busy throughout the shop year, regardless of their horse-power requirements. It is also to be deduced that since no credit has been allowed for shafting or motors allowed for group driving, it will actually pay to change existing shops to individual-motor drives."

Those who care to look into this matter further can probably obtain a copy of the paper which he presented before the Railway Club of Pittsburg. The paper was written some time ago, but his method of analysis is quite as interesting now. The problem is so complex that results obtained in one establishment are of little value in connection with another, and it is never possible intelligently to consider the advisability of installing motor drives unless

conversant with the general character of work to be performed and shop practice in vogue.

That there is still a great difference of opinion on this subject is amply proven by the letters published a short time ago in the *Railroad Gazette*, and such differences will continue to exist until more accurate data, relative to machining and means of attaining full efficiency under imposed labor conditions, are available. The simple relations between cutting speed, feed and depth of cut for different material are known to but few, and upon this data depends the proper selection of apparatus.

I do not intend to discuss the various types of apparatus, and will only say that no radical departures have been made in principle of operation since 1901, when Mr. Gano S. Dunn described in this room the various means that were then resorted to for obtaining variable speed. The multiple-voltage systems using field weakening for intermediate speeds have been quite generally adopted during the intervening period, the apparatus having been greatly perfected, as stated above. Let me again repeat that everything depends upon the proper selection of motors and controllers, followed by intelligent installation and *operation*.

Many details I have not touched upon will, I hope, be covered in the discussion. I will close my remarks, which have already taken up more time than I intended, with a slide (*Fig. 4*), showing the interior of the new machine-shop of the Jeanesville Iron Works Company, which is characteristic of the modern shop of to-day. The Pittsburg lathe, shown on the previous slide, will be seen in the foreground; just beyond it, a 60-inch Pond lathe; and on the left, a Gray planer and Betts boring mill. The splendid facilities for handling material, the natural lighting and numerous other features mark the difference between this shop and those erected some years ago.

I stated in the beginning I would not be able to even allude to many matters of great interest, such as the radical changes in design that machine tools are undergoing as a result of improvements in tool steel and the adoption of the motor drive. In this connection I will only say that the

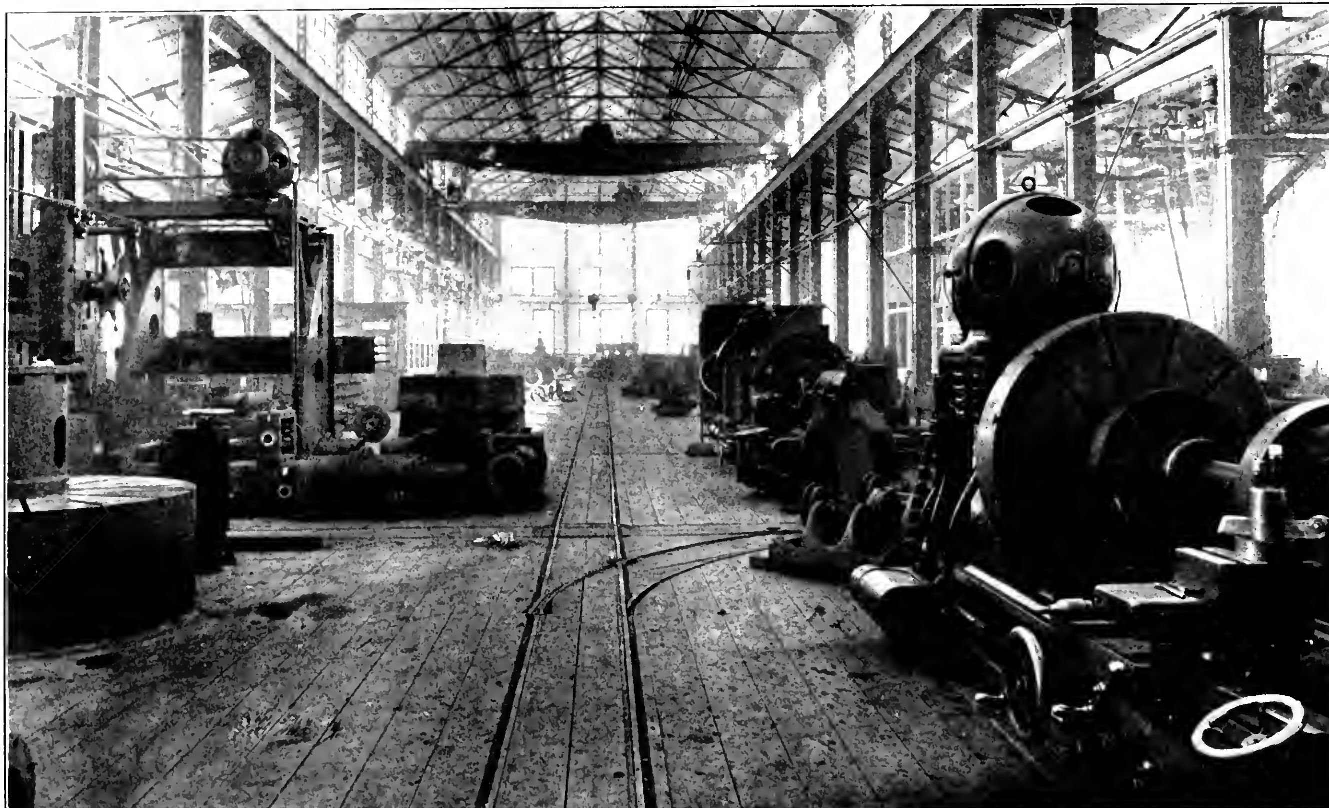


FIG. 4.—Interior of a modern machine-shop, showing location of motor-driven tools under traveling crane. (Jeanesville Iron Works Company, Hazleton, Pa.)

next ten years are likely to bring changes so radical in character that we can hardly realize them now.

DISCUSSION.

MR. GANO S. DUNN:—The present meeting recalls clearly the discussion on this subject before the Franklin Institute, in November, 1900, and a comparison of the views just expressed by Mr. Day with the conclusions of four years ago enables one to realize fully the substantial progress that has been made. At that time engineers differed widely upon many details that have since been definitely settled, and, in general, there is no longer any doubt as to the advantages of the electrical distribution of power in industrial plants.

The more general appreciation of the individual drive through a better understanding of shop requirements, and the realization on the part of the machine builders and electrical companies of the need for thorough co-operation, is rapidly placing this work on a firm footing that is in marked contrast to its position a few years ago.

A perfectly frank and intelligent treatment of each individual case is necessary, and one equipment yielding a proper return is a better advertisement than a dozen "show plants." Those who do not comprehend fully the situation, through lack of experience in industrial work, frequently attach a certain amount of mystery to the motor drive, but manufacturers who count on a certain return from every dollar invested for betterment or extension are not greatly interested in advantages so subtle that they cannot be defined.

An engineering department competent in not only the electrical details of manufacturing plants, but in the mechanical and executive features also, with sub-departments to specialize on different industries, is not only of inestimable value to the electrical companies in establishing a basis for intelligent design, but insures for their customers *the results* that they are primarily after.

In the four years that have elapsed since the last meeting on this subject, no radical changes have resulted in the various systems used for obtaining variable speed, although

certain of these systems have become well established and quite generally adopted by large manufacturing companies. Where a given shop is to be equipped with motor drive, and the one object is to attain the highest general efficiency of the plant, those in charge of the work can have the greatest latitude in their decision. The multiple-voltage system, in such instances, possesses marked advantages that, at the present time at least, are not true of other systems. Motors operating on this system give even less trouble through commutation or heating than the same motors running at constant speed, which is not true of any of the systems where a wide speed range is obtained by field weakening only.

All the considerations referred to at some length by Mr. Day should be carefully borne in mind by customers purchasing for their own use. The machine builders, on the other hand, are restricted by certain commercial factors which prevent the selection of apparatus that cannot be operated in the ordinary plant where their product is solicited. To meet their requirements, we are called upon to exert our best efforts toward the development of single-voltage, variable-speed motors. Modern manufacturing methods call for machine tools designed for special duty, and this class require a comparatively small range in speed.

It is true that machine-tool duty, through its intermittent character, will permit of a special basis of rating; but, until some standard is adopted, the customer is likely to be misled, unless he clearly defines the overloads required and confirms them by actual test.

The advantages possessed by the individual drive ultimately depend on the reliability of the apparatus—a factor too often overlooked; and the desirable system is one that not only fulfils requirements, but, at the same time, assures a minimum of interruption through controller or motor troubles.

Controllers for machine-tool duty have undergone a marked evolution during the past few months, the latest types made by the company with which I am associated being so rugged and generous in all details of construction

that faults heretofore inherent in such apparatus have been wholly eliminated.

There are numerous details of this subject that no doubt could be discussed for an entire evening, but it is the consensus of opinion concerning the general problem that is sought now.

Not very long ago many hesitated to assert definitely that the motor drive had come to stay, while to-day it is only a question of what kind of motor drive. I feel perfectly confident that the individual drive will soon be adopted for even very small machines, and, indeed, Mr. Day's figures concerning the output of a number of the leading machine builders can leave little doubt in our minds as to the growing popularity of individual driving.

Mr. F. B. Duncan:—In discussing Mr. Day's paper it is well to take cognizance of the two great factors involved —the financial and the human

(1) Does it pay?

(2) How can we convince people that it does pay?

The first question has been well threshed out, and while many foolish investments have been made in motor equipment (as foolish investments have ever been and will continue to be), yet, on the whole, electrically operated machine tools have paid well.

Better placement of tools, especially the larger ones. The operation of powerful portable apparatus for use on the very largest work. Better crane service due to the absence of belts. The inestimable boon of the electric crane itself. Better light. Less dirt. Less danger to employees. Lighter overhead construction necessary in new factories due to non-existence of countershaft, etc. Fuel economy in many (but not all) instances; and last, and greatest of all, abundance of power to pull a cut of the most generous proportions at the highest speed permissible with the new high-speed tool steels.

The above reasons all are convincing that motor-driven tools pay, but chiefly the latter; for, as our foreign friends would say, "It is to laugh" to watch one of the standard belt-driven tools endeavor to cope with an ambitious ma-

chinist in combination with a well-made tool of the new high-speed breed.

Properly presented and explained to a manager or superintendent of ordinary intelligence, electrical equipment of machine tools is self-convincing, and this brings us to the second question:

How can we convince people that it does pay?

It is very fortunate that the new tool steels had arrived on the scene just when they did, as they necessitated the complete re-design of the existing machine tools, and if the electrical fraternity do their duty the new tool designs made necessary will be arranged with electrical operation as the *primary* and belt drive as a *secondary* consideration.

No permanent advance in electrical operation of machine tools will be made until the motor and the tool are designed for each other as much as the old cone pulley was designed for the machine on which it was used.

An electro-mechanical tool concern, or rather a multitude of them, is the crying need of the hour. Electrical-machinery builders and machine-tool builders have each wrestled with the problem separately and with each other collectively, and the result has been some progress, and once in a thousand times a fairly passable design has been worked out; but, on the whole, a most atrocious lot of abortions have been foisted on the long-suffering public.

It is not the fault of the designs of either part of the equipment. The motor makers made good motors and the tool men made good tools for their purpose (before the new steels made them ridiculous); but the trouble has been and is that the problem has not been attacked in the right way and very little progress (comparatively speaking) has been made in the past ten years in regard to perfecting the electrical operation of metal-working tools. The *quantity* has increased enormously; the *quality* has remained about stationary.

In a shop exclusively electrically operated with over 500 motors, this fact was forcibly brought to the writer's attention. Some motor-driven tools were installed over twelve years ago, and yet the same crudities of attachment

to the tool are being perpetrated on the recent tools as were on these installed in the dawn of motor drive.

The illustration (*Fig. 2*) shown by Mr. Day emphasizes this fact; for, although a good example of the best up-to-date practice, it is yet a disgrace to the art and an eyesore to any one who reflects for a moment on what might be accomplished by a progressive concern that would merge the tool and motor design into each other with the view of turning out the most efficient unit possible.

Some may ask what this has to do with convincing the managers of the metal-working industries that motor drive pays.

It has everything to do with it.

A progressive superintendent or manager partially acquainted with the possibilities of electric drive hears something about it (probably from an enthusiastic electrical salesman), decides to order a trial machine; when he gets the outfit, the appearance of which nearly always violates the ethics of correct design (and whose actions too often are unreliable, especially in regard to speed control), he is apt to become discouraged in his search after electrical knowledge.

What is needed (and this cannot be emphasized too strongly) *is a complete re-design of present machine tools with motor operation alone in view.*

The idea must also be abandoned that standard motors can be bought and "hitched up" to a tool originally designed for a belt drive, with the result of obtaining a satisfactory outfit.

It can only be done in a very few instances; and what is needed is an entire line of machine tools designed electrically and mechanically for the production of the *greatest* amount of work in the *shortest* possible time.

The tool builders and electrical men may well take a leaf from the experience of the automobile manufacturers. Until the latter abandoned standard motors, engines, bodies and gears, and evolved, appropriated and combined types made necessary by the exigencies of the case, no substantial progress was made; but since they have evolved new

types of engines, motors, running gears, bodies, etc., the industry has advanced by leaps and bounds until it is one of the marvels of this wonderful century.

The motor-driven machine tool will make a similar advance as soon as a firm is found with nerve enough to break away from old traditions, and put a few record-breaking tools on the market whose electrical and mechanical design is of the twentieth century.

The requirements are simple and severe: machinery heavy and stiff enough to stand the maximum cut the work will stand, equipped with a motor designed to give the proper speed variation, and powerful enough to pull the maximum cut, built into the machine as an integral part of same.

A few tools of this type set up alongside of belt-driven apparatus will soon convince the most skeptical that motor drive pays, for such machines will forge ahead of our present apparatus, much as a high-speed automobile distances a horse and buggy.

We may also look forward to the time, not far ahead, when recording instruments on the tools will give the superintendent a check on production and on the individual operator, that will enable him to keep track of the "personal equation" in the shape of lazy workmen in a most accurate and impartial manner, with corresponding benefits to the output of his tools, the dividends of the stockholders and the pay envelope of the diligent mechanic.

Mr. H. B. Emerson:—I came here this evening to listen, rather than talk; and, having listened, feel that the subject has been so ably handled that there is little left to be said.

I agree most heartily with Mr. Day on the outlined details, but have made note of a few points which may bear mention.

First, the prime question to the manufacturer who intends equipping his shop is, "How to obtain maximum production at minimum cost." This is a question which is not easily answered, and means that he must study his requirements fully to get best results, or employ an engineer who has made machine-tool driving a study and is thoroughly

familiar with modern shop practice. Every case must be treated individually, for what might be best in one case might not be most economical in another. There have been many installations made within the past few years which have not been treated in this way, and as a result, the owner, after paying a large sum for his equipment, can produce no more than with the old drive. He is naturally disgusted and condemns everything electrical.

I have also seen some old machines re-equipped at considerable expense, only to find that the motor applied was of too great capacity for the construction of the machine, and in such cases it means capital tied up, from which no revenue can be derived.

A second very important point is the "ease of control." With the belt drive, and with some electric drives, the operator has to leave his work to shift a belt or change his controller, which may be placed at the side of the machine. This takes time, and wasted time means lost money. If the control is properly applied, the operator does not have to leave his work, and not only saves time, but constantly keeps his machine working at its maximum.

A third point for consideration is the "amount of speed variation required." This, of course, varies with the installation; but it seems as though the trend of industry is toward specialization, and where this specialization increases, the need of a large range of speed control decreases as one machine does its specific work, and this same class of work comes to it day after day and week after week. In such installations standard, or nearly standard, apparatus can be used; but in repair shops or factories, where all kinds and classes of work are coming to the one machine, a greater range of control is required.

There are a great many methods of electric speed control, each with its advocate, but I believe the best engineers recommend the three- and four-wire system, combined with field control, tending to keep their minimum voltage to a maximum; or, in other words, trying to approach as near a constant potential as possible. There are also a great many mechanical speed variators on the market, all of

which are more or less imperfect in design. If such a device is perfected, it will undoubtedly revolutionize machine-tool driving, as a constant-speed motor only will be required, and the alternating current (or induction motor) would supplant the direct-current motor now in use. However, all the commercial devices of this kind that I have seen are either very inefficient, too complicated or too bulky for the duty required of them, and it seems better to maintain the drive as a unit and obtain the variation electrically through a reasonable range.

In conclusion, I would again call your attention to the advisability of consulting a thoroughly competent engineer in laying out new machine shops, or in re-equipping old ones, for it is cheapest in the end.

Mr. F. M. Kimball:—I agree quite heartily with the general conclusions set forth in Mr. Day's paper. The points I should emphasize particularly would be:

(1) That, in the selection of motors, the financial aspect of any proposed investment must be considered fully as much as the technical aspect. From the engineering standpoint alone, we would often advise a certain form of equipment which, when the necessary investment to procure it is considered and the cost of operation and maintenance is compared with increase in production gained, would be found unwise.

(2) In other classes of business, where, at first sight, an installation involving low capitalization might seem desirable, a further consideration of the value in the increased product and the decreased expense of this product, due to the elimination of manual labor or attendance, will fully justify us in spending the larger amount of money to begin with.

(3) There is no doubt that, as a general statement, the cheaper the electricity supply becomes, the lower the manufacturers are able to produce good motors; the higher the trades unions drive the price of labor and the larger the market becomes for any given item of product, the more advantageous will it become, from all standpoints, to adopt individual drive as against group drive.

(4) I am still of the opinion, advanced some two years ago, that, in general problems of machine equipment, speed variation by the motor of one to three on single voltage, and one to six on double voltage, is all that is necessary. The remaining requirements can better be met mechanically. The coarse changes in speed can nearly always be made by change gears or their equivalent, and the intermediate and finer gradations of speed can be effected electrically.

(5) While, from the theoretical standpoint, the individual equipment of every tool and the use of motors having extremely wide speed ranges may be desirable, yet commercial considerations, which cannot possibly be overlooked, will largely modify this conclusion when definite manufacturing problems are being worked out.

MR. R. T. LOZIER:—Mr. Day has quite fully stated why electric motors have been selected in a number of important machine-shops to drive certain of their tools, and we are all willing to grant that the output of such tools is increased by their use, and that that is a good reason for their adoption.

The French say, "A man is happy when he knows what he wants." This may be a shop superintendent as well as any other fellow. Now, therefore, the main question is just what does the shop superintendent want in the way of a motor equipment?

In an article that I have just completed on this subject for the *Electrical Magazine* of England, I suggested the following plan:

Divide the tools of any shop under two general classifications, viz.:

(1) Tools which warrant the investment for individual motors.

(*a*) Those in which it is desired to vary the speed and to have a source of power that will stand up to the work put upon it; so that as a resultant of these two factors the output of the tool is materially increased over that obtained by the belt drive with its limited speed ranges and inefficient power transmission.

(*b*) Those tools in which the convenience gained by the individual motors is sufficient to warrant that investment, viz., permitting of a clear space for the overhead cranes to work in, and, with improvement in light and ventilation, more economic shop arrangement; and particularly those tools that cannot be conveniently reached by line shafts and belts.

(2) Tools which do not warrant the investment for individual motors.

These tools are those that run at fixed speeds not often varied, and which occupy that part of the shop where group driving by line shafts does not interfere with the crane work.

Having made this first general classification, the next step would be to select the speed range for the variable speed tools and the method for obtaining it. This can be determined easily in the following manner:

The rotary machine tools may be said to represent the limits of speed variation, and the following general rule applying thereto can be stated as follows:

The minimum or lowest speed of the range that such tools will run at is determined by the hardest material to be machined when taking a cut at the largest diameter that the dimensions of the tool permits.

The maximum or highest speed of the range is determined by the softest material and the smallest diameter at which the tool will work efficiently.

Let us assume that a 26-inch lathe represents the maximum speed requirements of average work, and that it is to handle high-carbon steel at a cutting speed of 12½ feet per minute.

If the carbon machine has a circumference of 26 inches diameter, the spindle (or face plate) of the lathe will run at 1·8 revolutions per minute.

If this same lathe is to machine cast iron at 120 feet per minute cutting speed, and as small a diameter as 2 inches, then the spindle (or face plate) will run at say 225 revolutions per minute.

This gives a ratio of about 125 to 1.

Now, of course, no electrical system can ever give that

range; so we will take two back gears at 5 to 1 each, and a motor having a 5 to 1 ratio of speed variation also (5 times 5 times 5 = 125). With both gears in and the motor running at its lowest speed we get 1·8 revolutions per minute.

At this point we increase the speed of the motor by selected increments until we reach (1·8 times 5) 9 revolutions per minute.

The second gear is then dropped out, the motor put back to its slowest speed and without gear reduction we still have 9 revolutions per minute. We again speed up the motor and get (9 times 5) 45 revolutions per minute.

The first gear then drops out and the motor is brought down to its lowest speed, driving direct at 45 revolutions per minute, which speed is increased by the motor's control up to (45 times 5) 225 revolutions per minute.

For such tools as do not require such a broad range but one back gear is used or the motor drives directly on to the tool-shaft as the speeds may require.

It will be noted that all the intermediate changes are made by the motor, which can readily be varied in its speed while the tool is doing its work; so that this method provides the shop superintendent with a perfectly practical range of speed that will cover almost any class of work with as many steps in his motor-control as he may want, and which can be applied to any extent he may desire. The nature of the work may determine other ratios to be more desirable; that, of course, can be worked out in each case by the rule given above.

Now, having determined what tools are to have individual motors and, secondly, what their speed range should be, the next point will be to determine how much power each tool will require and the kind of a motor to produce it. No general rule can be laid down, I believe. The nature of the cutting-tool, the method of transmitting the power to it through the machine's driving gear, and the losses involved in that transmission, vary in each case and their values can only be obtained from actual tests.

Modern machine-shop practice, as concerns cutting speeds and feeds, has made worthless the figures that were furnished for belt drives.

This work requires the services of an engineer who not only understands the mechanical requirements of the tool, but who will also be able to lay out a system in which all the requirements of the electric plant will receive their proper value.

MR. JAMES CHRISTIE:—Mr. Day's paper brings out very clearly the importance of carefully considering the nature of the work and the general conditions of practice which are to be encountered before deciding on the details of the electric-power equipment of a shop. Certain machines, from the nature of their operation, or the character of the work which they are to do, can be most advantageously operated in groups, from a countershaft driven by a constant-speed motor. Others require an individual constant-speed motor, as, for instance, where location is important, and crane service must not be interfered with; and still others require individual variable-speed drive.

Small lathes and other small machines do not require heavy crane service, nor is the difference in diameter of work sufficient to make speed control a necessity, so that with machines below a certain size, it is often best to drive in small groups from a constant-speed countershaft. With boring mills and large lathes, the variation in diameter of the work, and, consequently, the widely varying peripheral velocities and the necessity for having crane service, make individual variable-speed drive most desirable.

Individual constant-speed motor drives have been in use for many years in the Pencoyd bridge shop. This method of driving is generally very suitable for bridge-shop machines, owing to the large size of punches and shears, and the necessity of locating in exactly the proper position without interfering with the crane service. The functions of these machines are, at the same time, such as not to require variable speed.

We have recently installed a multi-voltage system in our new machine shop, and although it has not been in operation long enough for complete tests to be obtained that would be of value in comparison with belt-driven shops, we have had opportunity to draw certain general conclusions

as to its value. Variable speed is a distinct advantage in such cases as the facing of discs on lathe or boring mill; for, as the tool proceeds from circumference to center, a comparatively uniform cutting speed can be maintained without interrupting the operation, simply by altering the speed of the motor.

The effect of having a wide range of speed under easy control is an encouragement to the workmen to experiment with cutting speeds, and they quickly learn the maximum speed which material and tool steel will allow. A great deal of the trouble incident to the use of a multi-voltage system arises with the controllers. Most of it is confined to the controllers on the smaller machines; the small nature of the work requiring far more frequent stopping and starting, with the consequent wear and tear, than on the larger machines. The system provides for six voltages, ranging from 40 to 240 volts, and intermediate speeds can be obtained by throwing in the back gears or weakening the motor field.

Field regulation has not proved entirely satisfactory in some cases, sparking and momentary variations in the motor speed being the consequence. On this account, it was found desirable in some cases to cut out points on the controller that threw in the field resistance, and to rely only on difference of voltage and the back gears for speed changes. It is best that reduction in speed be obtained whenever possible by the use of the back gears, rather than by using a lower voltage, not only because a higher efficiency is insured, but also to avoid having too large a proportion of the shop power drawn from the low voltages, with consequent overloading.

The increased cost of installing a multi-voltage system over that of a constant-speed system is considerable; the difference arising not only from the more complicated nature of the wiring, starting devices, etc., but also largely from the fact that a motor for a multi-voltage system must be five or six times as large as the constant-speed motor to do the same work. The motors for a variable-speed system being larger and the starting devices, etc., more complicated

than in a constant-speed system, the cost of repair and maintenance is, of course, greater in porportion.

These various methods of motor drive are each best suited for certain conditions, and, if properly applied, will, undoubtedly, produce more satisfactory results and reduce the shop cost; but it is necessary that the bearing of every condition be carefully considered.

PROF. ELIHU THOMSON:—This is a specialty to which I can hardly claim to have given more than the most general attention. Our business has so many ramifications that it is impossible to follow each one of them in detail. There are men who have given careful and special study to the particular subject under consideration, and to these I would defer.

My general opinion is that there is no hard-and-fast rule which can be laid down, everything depending on the conditions of use of the machine tools. In some cases the group drive will undoubtedly hold its own, and perhaps in other instances the belt, counter and line shaft will be retained. The individual drive is likely to continue to replace the older forms, particularly for the larger tools, and for those kept in active service at maximum output. The accumulation of data on the subject is gradually becoming such that it will be possible before long for competent engineers to determine the desirability or undesirability of resorting to individual operation by motors.

A modern works of any extent now requires its engine-dynamo in power-house to be conveniently located, with connecting lines from which power is obtained from electric motors, sometimes to drive line shafting, serving groups of machines more or less extended, and at other times driving certain machines individually.

The case of each factory or workshop is, it seems to me, one which needs to be considered by itself, with a careful estimation of all that goes to increase the economy of the operation.

MR. W. COOPER:—The subject, "Use of Electric Motors in the Machine Shop," is one to which I have given considerable thought, and have assisted in making a great many

different applications. The conditions of operation of the machinery of a machine shop are not ideal for an electric motor. In the first place, the work done by nearly all machine-shop tools is very intermittent and variable in character. Ordinarily the work being done calls for a very small amount of power, while at times the demand is very great. This is especially true in the individual application of motors to the machines. It is, therefore, necessary to equip any given machine with a motor which will have sufficient capacity to do the maximum amount of work. Such a motor will necessarily be operated a greater portion of the time at a very small percentage of its capacity, and consequently comparatively inefficiently. This very condition has led to the use of motors that were entirely too small for the maximum work that they will be called upon to do, the assumption being that they would be large enough for the average work, and could probably stand the strain for short periods of the maximum demand.

Another reason why the use of motors in machine shops is not more general and is not increasing more rapidly is that the applications made bristle with errors.

In many instances the motor has been out of all proportion to the work to be performed; in a great many cases unnecessarily powerful, and in a great many cases too small. In the former case, of course, the motor does its work without distress, while in the latter case, in a good many instances at least, absolute failure has been the result. In the individual application of the so-called variable speed motors, the motor is usually overworked at some point in its range. The fact is that if a very wide range of speeds is demanded from the motor, its size increases very rapidly with the increased range, and soon becomes inordinately large for the smaller class of machines. If a very wide range in the motor is employed, the electrical equipment often costs more than the machines to which it is applied. While this does not necessarily signify an uneconomical arrangement, as the advantages derived may many times offset the increased investment, still the increased first cost is a factor to be dealt with. During the last two

years the individual application of motors to machine-shop tools has been thrown into a very unsettled condition, so much so that it is difficult to determine at the present time all the features governing the case. During this period the high-speed steel has come into quite general use. At the same time the underlying principles involved in the use of motors for machine-shop tools has become better understood. During the first experiments in the use of the multiple-voltage system for getting variable speeds, the motor got decidedly the worst of the bargain. There seemed to be some idea that on the lower voltages and at the slower speed the motor could keep up its end on account of its running at such a slow speed that there was no tendency for the motor to spark. It was soon found, however, that there was something wrong in the arrangement, and that the motors would not have the pulling power at the slow speeds, and also that the inherent regulation on the low voltages was very poor. Also in the earlier uses of the multiple-voltage system no attempt was made to graduate the speed by field regulation, the entire speed range being covered by varying the voltage. This had the disadvantage of requiring either a very low voltage for the slow speed, or a high voltage for the highest speed, and to build a motor that would operate satisfactorily at the two extremes and still be moderate in size, seemed to be a very difficult task, which indeed it was. Another point that was decidedly wrong in the first uses of the multiple voltage for variable speeds was that variation between the voltages was made a constant, bringing the voltages in as near as possible arithmetical progression, while they should be in geometrical progression. This is certainly obvious, when the matter is given consideration and figured out carefully on the basis of increased cutting speeds or increased rotative speeds. When shunt-field regulation was applied in connection with the multiple-voltage system, it was found that a wider range could be covered satisfactorily, or the same range could be covered with a narrower range of variable voltages.

In a paper which I read before the second meeting of the

Cincinnati Chapter of the American Institute of Electrical Engineers, February, 1903, and published in the *Transactions* of the American Institute of Electrical Engineers for April, 1903, some of the fundamental principles underlying the use of a shunt-wound direct-current motor for variable speeds are pointed out. In that paper is shown that where formerly the four-wire circuit for a multiple-voltage system with a ratio between the extreme voltages of about six to one had been used, the same results could be accomplished by using a range of voltages of about two and one-half to one and a three-wire system. The following rules were deduced as conclusions from that paper:

(1) The total range of speed, using both variable voltage and field regulation, will be as the square of the range of voltages.

(2) The change of horse-power will be directly proportional to change of voltage on armature, field being constant.

(3) The change of horse-power by change of field strength will be inversely proportional to change in speed, the voltage on the armature remaining constant.

(4) The relative size of motor, as referred to the maximum speed, will be directly proportional to its speed variation when using variable voltages.

(5) The relative size of motor, as referred to the maximum speed, will be as the square of the speed variation when using field regulation.

With this understanding of the matter of the use of variable-speed motors, there should be no difficulty in providing a suitable motor for any given range of speeds, providing the power required is absolutely known. Right here I want to put in a strong plea on this point. In all the applications of motors to machinery in a machine-shop, let it first be fully and positively determined how much power any individual machine or group of machines will require. Having fully determined this point, let there be no mistake made in providing a motor powerful enough to do the work. If the motor to give the necessary power and to cover a wide range of speeds, if variable speeds be desired, should

be abnormally large, gearing should be resorted to. It is far better to burden the machine with a complex set of change gears than to equip it with a variable-speed motor that will not be able to meet all the demands which will be made upon it. It is the writer's opinion, however, that it is not desirable to have speeds overlap; that is to say, that one change of gears should begin where the previous one left off, plus, of course, the change of speed due to the speed range of motor, the motor being able to fully take care of the intervening speeds. By this arrangement the operator will not be hampered by duplicate speeds, and he cannot possibly injure the motor.

WATER REQUIRED FOR GAS ENGINES.

According to the *Engineer*, the quantity of water required at the ordinary temperature of 60° F. inlet, and 150° outlet, to keep the cylinders of gas engines cool is 4·5 to 5 gallons per indicated horsepower-hour. The jacket pipe should be from 1 to 2 inches diameter for engines up to 20 horsepower, while for larger engines the sizes are generally 2 to 3 inches for the inlet and 2·5 to 3·5 inches for the outlet. Tanks for circulating the water are generally made with a capacity for furnishing 20 to 30 gallons per indicated horsepower.

SPONTANEOUS IGNITION OF COAL.

Alfred O. Doane, in *Engineering News*, August 18, 1904, states that, in order to reduce the danger from heating as much as possible, the following precautions should be observed. The storage bin should be roofed over. No wood should be used in its construction. The depth of the coal should be reduced as much as possible; it is best not to exceed 12 feet. All iron work, including posts, should be protected by concrete against fire and acid water from the coal. It is advisable to have a circulation of air under the bottom and around the sides of the bin or pocket.

As almost all coal will heat to some extent, it is desirable to know that the safe limit be not exceeded. This may be determined by thermometric tests. A simpler way is to drive in ⅝-inch rods at convenient places, allow them to remain a suitable time, then remove and test by the hand. An experienced man can tell by the feel if the coal is dangerously hot. If the temperature of any part of the pile is above 140° F., it is time to take active measures to prevent further heating.

When the coal in the interior of a pile ignites, the heat cokes a layer of coal around the glowing nucleus, which will shed water and make it difficult to quench by playing water on the surface of the pile. A good way is to drive in a pointed 2-inch pipe, the lower 3 or 4 feet perforated with ⅜-inch holes, to the depth of the fire as indicated by the test rod, connect the upper end of the pipe with hose, and force water into the heart of the fire.

Mining and Metallurgical Section.

Stated Meeting, held Thursday, April 21, 1904.

The Copper River Country, Alaska.

By W. R. Abercrombie, Major U. S. A.

(*Concluded from p. 310.*)

THE EFFECT OF THE CONSTRUCTION OF THE TRANS-ALASKAN MILITARY ROAD ON THE DEVELOPMENT OF AN ALL-AMERICAN ROUTE THROUGH CENTRAL ALASKA.

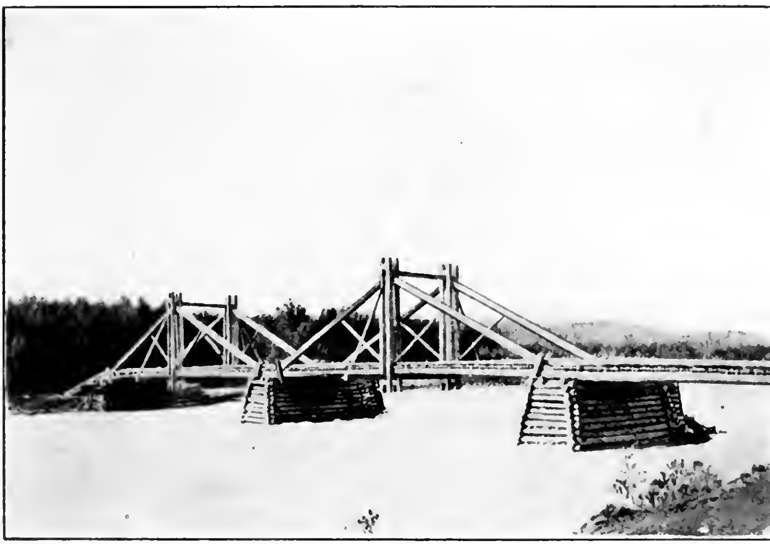
On my arrival at Port Valdez, in the spring of 1898, I found some 4,000 people that were at a loss how to proceed into the interior from the coast, owing to the lack of knowledge of the topography of the Copper River Valley. So far as any accurate information was involved, they were helpless. It was estimated that the outfits, cost of transportation and other incidentals had cost these people and their friends over $2,000,000. During the Fall of that same year over 75 per cent.of these people returned to their homes in the States with very little more knowledge of the country than they had prior to their visit, and utterly unable to explain to their friends why they had failed in their undertaking. In the Fall of 1901 the entire valley, embracing the main and sub-drainage of the Copper River, was as well known as that of most any mining district in Montana. In this interval of time the entire country had been explored, a road and bridges had been built, over which traffic could be continued during the entire season; road-houses had been built and several hay ranches located. The gross expense to the Government had been $193,000. To offset this expenditure, the prospector had taken out of the ground $185,000 of placer gold, while the discovery of copper-bearing ores bid fair to induce the investment of millions of dollars of capital, which, if it had not been for the construction of the trans-Alaskan military road, would have remained undiscovered and undeveloped for many years to come.

AGRICULTURAL POSSIBILITIES OF THE COPPER RIVER VALLEY AND ITS ATTRACTIVE FEATURES FOR THE SMALL FARMER.

Having watched for the past twenty years the growth of our former northern frontier, namely, Dakota, Montana, Idaho and Washington; having traversed the Yellowstone, Gallatin, Spokane and other valleys prior to the advent of the rancher and the railroad, I feel qualified in a measure to give an intelligent opinion relative to the capabilities of the soil and the prospects of the small farmer, who is constantly on the move in the search of a home in a new country.

I find the conditions as varying in different parts of the Copper River Valley as the great range of climatic conditions would naturally dictate. The disappearance of the snow and the sprouting of the grass varies at least forty-five days in different portions of the valley. Along almost every route that has been traveled by pack-animals will be found scattering spears of timothy and grain. I shall first consider the route traveled by the pioneer horseman of the season of 1898, as that was the only year in which pack-animals were used over the route from Valdez to Copper Center via the Valdez Glacier and Klutena River. During the season of 1899, spears of timothy and grain were found along this trail, which would indicate that the original seeding of 1898 re-seeded itself with the result of a volunteer crop in 1900, and is to my mind conclusive evidence that, when acclimated, grain and hay will both mature and bring forth abundant crops. From the evidence obtained in a small experimental garden, it is an assured fact that potatoes, turnips, beets, peas, lettuce, radishes and possibly many other vegetables will grow in abundance when the proper soil, exposure and drainage are obtained. As the existence of the small farmer is conditional on the laws of supply and demand, it will be necessary in this instance, having found the supply, to point out the probable demand. Two hundred and fifty miles inland from Port Valdez in a northerly direction lie the gold fields of the Chesna mining district, which, in my opinion, will in the next few years produce many millions of dollars of gold dust. There is to-day, aside from the 200 or 300 head of horses, the property of the

Government and individual owners, absolutely no means of transportation between these two points—Valdez and the head-waters of the Chestochena River. A pack-animal loaded with forage at Valdez, if no means of subsistence were to be had *en route*, would consume more than the forage he could pack before reaching his destination, which fact is attested by the scores of dead horses whose carcasses marked the advancement of settlement along the trans-Alaskan military road. Hay and grain to-day at Port



Queen Truss Bridge, spanning Kentena, 100 miles from Valdez, constructed with ax, auger and chisel, without nails or bolts.

Valdez, original cost and marine transportation added, will average $40 per ton. This forage cannot be transported into the Copper River Valley to the crossing of the Tonsena for less than 25 cents per pound, and then the margin to the freighter is extremely meager. Therefore, the opportunities to-day awaiting the small farmer who will select his homestead judiciously along the trans-Alaskan military road with a view of erecting thereon a bunk-house and barn for the accommodation of man and beast, and for the cultivation of forage for the animal and the vegetable product for

the man, is in my opinion so much more enticing than the inducements held out by the bleak prairies of Dakota or the wind-swept valleys of the Yellowstone as to be beyond comparison.

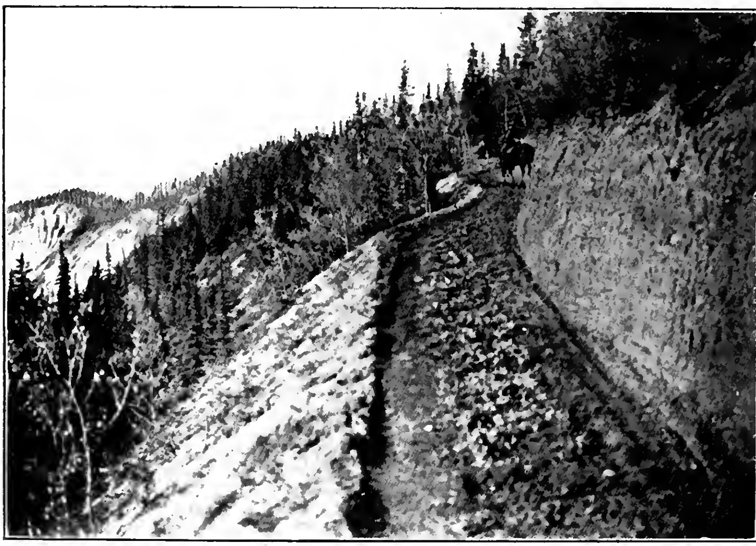
On this subject I would say that I am more profoundly of the opinion to-day than ever before that the valleys of the sub-drainage of the Copper River Valley will in future years supply the demand for cereals and vegetables, if not meat, of the thousands of miners who will be required to extract the vast deposits of metal from mother earth in the Chettyna, Kutsena and other districts. Referring to the available or arable land for the cultivation of forage, I shall eliminate the Coast Range entirely, for the reason that owing to the heavy fall of snow the spring is generally one month later than in the Copper River Valley. The crest of the mountains being capped as they are with monster glaciers, cause a daily precipitation from the 1st of July until freezing weather in October. While vegetables and fodder grow luxuriantly in the Coast Range district, forage must be treated as an ensilage, as owing to the constant rain it cannot be otherwise cured. Following the south fork of the Tonsena will be found thousands of acres of available land for cultivation, which, having been burnt over years ago and divested of its covering of moss, needs now only to be cleared of the dead spruce timber that encumbers it when it is ready for the plough. Five miles north of the Tonsena bridge are tracts of land well timbered and drained that is likewise available for agricultural purposes. A few miles north of the Tazlena is a stretch of sandy, loamy soil, with a southern exposure that looks attractive. At the mouth of the Tonsena River is a large hay meadow many hundreds of acres in extent, in which quantities of hay could be cured.

While the collection of information relative to the mineral possibilities of Central Alaska have been intelligently and energetically pushed forward by the U. S. Geological Survey, in my opinion the backbone of the settlement of this mighty valley—its agricultural resources—have been sadly neglected for less important researches along the coast.

COPPER DEPOSITS OF THE WRANGELL GROUP OF MOUNTAINS AND THEIR RELATION TO THE COMMERCE OF THE PACIFIC COAST.

The Copper River Valley is generally conceded by geologists to have been an ancient lake bed, the center of which was probably where now stands the colossal Wrangell group of mountains. Most prominent among the thousands of peaks and shafts that appear to pierce the very sky with their snow-clad and glacier-laden shoulders are Mounts Sanford, Drum, Blackburn and Wrangell, varying in altitude from 12,000 to 16,000 feet. The form of this group is almost a circle, drained on the north, west and south by tributaries of the Copper River; northeast by the head-waters of the Tanȧna; southeast by the head-waters of the White. Of the interior of this group little or nothing is known. The entire range is eruptive in character, with a central cone (Mount Wrangell) which acts as a vent for the vast furnaces many miles below in the earth's bowels. This crater is more or less active from time to time, and has, on more than one occasion in the past, rudely disturbed the surrounding country for many miles by its convulsions, when great quantities of smoke, cinders and molten lava were belched forth from its crater. During its period of repose steam jets are generally seen playing through small indicators or blow-holes on the north side of its dome-shaped crest, which, after an eruption has ceased and the lava cooled, soon becomes covered with a sheet of snow. After the mighty effort of the internal fires ages back, which push forth this mass of volcanic mountains, the cooling period followed, when the formation was rent and cracked by the reactive agents, leaving, as a result, deep and irregular canyons, exposing to view the lower levels of the formation which had originally reposed thousands of feet under the bottom of this ancient lake bed, the drainage of which is to-day the Copper River. During the earlier part of the last century the Russian Baranoff was attracted by the ingots of copper and implements of the same metal that he found in the possession of the Indians living along the Chettyna. His efforts to obtain further information, however, bore no fruit.

The next effort of any importance, so far as I am aware, was that made by the Calumet and Hecla Mining Company, of Boston, in 1898, who sent their agent, one E. J. Cooper, to search for this copper in the Chettyna country. The nearest this agent penetrated to his objective point was the mouth of the Klutena River. It is needless to say that his mission was a failure. In 1899 two plucky and resourceful prospectors induced the old chief, Nicolai, in consideration of gifts of food, to show them this location, which proved



Wagon road down Copper River bluffs to Gakona crossing.

to be a bornite deposit of great value. The richness of this copper strike, the ore of which, on being assayed, showed the presence of 85 per cent. copper, soon spread along the entire Pacific Coast.

Personally, I have traveled over more territory than any other white man in Central Alaska, which has given me the opportunity to observe the formation of the various mountain ranges and to form an opinion on this section of Alaska as a whole; in addition, I have made it a point to request of every intelligent prospector a written or verbal

report of his research. For the benefit of the public at large, I have digested these opinions, which, together with my own observations, which extend to the early periods in the mining histories of the great silver and copper camps of Colorado and Montana, based on this information I shall give an epitomized opinion of the attractive features of the mineral deposits in the Wrangell group of mountains as I have seen them. The formation of this group being circular, to more readily understand the trend of the mineral deposits, the Wrangell zone or district will be treated as a circle. The northeast segment of this circle, which is drained by the head-waters of the Tanana, is thought to be the richest portion of the zone; but owing to its great distance from seaboard and the presence of such masses of ore in the southwest division of the zone, no location, as far as I am aware, has been made there. The southeast section, which is drained by the White River, is, owing to its inaccessibility, rendered so by the crossing of Scoloi Pass, hardly worthy of consideration as a commercial proposition. Leaving the Wrangell zone for the main range dividing the Tanana and Copper Rivers, will be found quantities of copper and galena ores, although the ledges are not so massive or anything like as heavily mineralized as those in the Wrangell district, where the ledge matter is simply astounding. Ordinarily, we have been used to look upon a mineralized zone as some 10 or 20 miles in length; in the Wrangell group we have almost a circle 80 miles in diameter, the mineralization of which is simply marvelous; and yet, valuable as these concentrates are (and there must be some mighty ore deposits in this vast area of volcanic matter), they are as valueless commercially as so much sandstone without the aid of the railroad and reduction works. Low-grade ores are met with from Keystone Canyon westward; in fact, on the flood plains of Lowe River bowlders showing native copper to the naked eye can be found. If one group of mines could deflect a transcontinental trunk line, as is the case in Butte, Mont., and the great Northern Railroad, what will this mighty zone, which, considering surface indications as final, and which contains a dozen

properties of far greater value as copper propositions than have ever been mined in the State of Montana, do for the commercial interests of the Pacific Coast? If the purchase of Alaska was an epoch in the history of the Pacific Coast, the opening of Central Alaska to the general public by the War Department will be an epoch in the history of the copper-mining industry in the Western Hemisphere.

GOLD DEPOSITS ON THE HEAD-WATERS OF THE CHESTOCHENA.

During the summer of 1898 the Chestochena River (a literal translation of the name, which is of Indian origin, being "the river that rises among the Red Mountains") was reported to have fine gold in considerable quantities among its gravel. In September, 1899, I met two prospectors by the name of Hazlett and Meals, who had built a cabin and spent the winter on the Chesna, a branch of the Chestochena, in the mountains up near its source. From these men I learned that not only was there fine gold, but coarse gold, and in paying quantities. They had given the Chesna quite a thorough test with the result of demonstrating the existence of placer gold on all tributaries to the Chesna, and had followed the pay streak down the Chesna for some 7 or 8 miles to a point about a mile above its confluence with the Chestochena; there they had located a number of claims.

I made a thorough examination of the Chesna mining district into which prospectors had organized all tributaries of the head-waters of the Chestochena. It was found that not only did the Chesna and the small creeks at its head contain placer gold, but that Slate Creek, which is likewise tributary to the Chestochena, some 12 or 14 miles above the confluence of the Chesna and Chestochena, as well as Big Four and Buena Vista Gulches, were rich in placer gold. The country is extremely mountainous, the mountain sides being stained with immense brilliant red blotches of oxide of iron that shade off through yellows to a light gray. Some 5 miles up the Chesna, coming in from the left, is a small creek christened by the miners "Gold Creek," not on account of the gold, however, which it contains, but owing to the

brilliant coloring of the rock through which it has cut its stream's bed, which is the most gorgeous I have ever seen in the mountains. The water in the first place is as clear as crystal. The little canyon out of which this stream rushes has been worn away for half a mile or so, leaving the water to plunge over a sheer wall of this brilliantly colored rock 75 or 100 feet high. The refraction of light through the water from the highly colored rock makes it glitter and sparkle like gold; but curiously enough, the oxide formation appears to have nothing to do whatever with the auriferous deposits. Following up the Chesna to Meadow Creek, the oxide formation is crossed and a dull black slate formation encountered. Meadow and Ruby Creeks average from 1½ to 2 ounces per day to the man with five lengths of sluice boxes, and from an examination of the tailings I am satisfied that quite a bit of the gold was carried through the boxes.

Over a low divide from the head of Meadow Creek, not more than 1,000 yards, is Slate Creek, a barren, bleak, desolate-looking watershed. The gravel in the creek is dull and dead-looking—the last place one would look for gold deposits. The creek contains about sixteen full claims of 20 acres each. The discovery was made about the 19th of June, 1900, and from its gravel between July 10th and August 1st was washed out some $18,000 in gold dust. When I arrived there on the 15th of August, so slight an impression had the miners made on the face of the bars of the creek bed in taking out this gold that I was unable to find the ground that they had sluiced over until it was pointed out to me. On Miller Gulch, a small branch of the main creek, midway between its source and mouth, I tested the ground from the top of the mountain, which is about 2,000 feet above the creek bed, to the base, and was astonished to find pay dirt that would run from 15 to 20 cents a pan on the tops of these mountains.

In going down the mountain side the gold did not appear to be any coarser than that on the summit. In the face of a little cut bank on the side of this creek the dirt appeared to be peppered with fine gold to a height of some 9 or 10 feet above running water.

From a spot not larger that my hand, three nuggets were picked out, the largest weighing almost a dollar. Just below the bank, four men took out in ten days a grub stake of $1,000 each from an area not larger than that of the body of a wagon. The richest panful of dirt I am told ran a little over $6. Should the gold grow coarser as bedrock is reached, this deposit will be marvelously rich; but judging from the fact that the surface indications of the creek bed on the higher benches and the mountain tops carry about the same grade of gold as to coarseness, I am inclined to think that the Slate Creek deposits do not represent the main or coarse gold deposits. On the north side of the range from Miller Gulch are Buena Vista and Big Four Gulches, with precisely the same character of gold. At the mouth of Slate Creek, I found a number of location notices that had been made there by amateur prospectors in the summer of 1898.

Had these men been possessed of a little practical knowledge in placer mining, they would have found at a distance up the creek, not to exceed 2 miles, a short piece of rim rock that would have disclosed the fact to them that coarse gold was in the gulch. For the information of just such persons, who toil and labor with sled and boat simply to turn their backs on a fortune, I will state just how the professional prospector hunts for ear-marks or indications of the presence of gold in a mountain range. The formation (and by that I mean the presence of porphyry, slate or granite) does not materially aid the prospector in his research, as upheavals and a thousand other metamorphic conditions so change the rugged features of mother earth in 10,000 years that the original source from which the gold came has probably disintegrated and washed away thousands of years before the prospector came on the scene. As I have said, the professional prospector selects a long, swift stretch of water that shoots or sweeps all gravel from its rocky bed. In the course of time this stream cuts down through its rocky bed, leaving a rim or bank of rock on each side that, from exposure to the air, becomes more or less fractured, and into these fractures seeps moisture, which the frost

congeals, prying the fractures slightly apart, and the melting snow from year to year in its rush down this rocky canyon carries with it detritus, in which there is placer gold, should there be any on the mountain sides above; into these crevasses of the rim rock sooner or later drops one of these fine particles of gold, its specific gravity being so great that it soon buries itself in the fracture. The skilled prospector selects a favorable place in the rim rock, and with the end of his pick prys open the fracture, places the rock in his gold pan, and washing the mud therefrom with his hand into the gold pan, discovers the small grain of gold that has been lodged there by nature in complying with the laws of gravitation. This is termed rim-rock prospecting, and simply indicates the presence of gold in more or less quantities in the gulch above, and its discovery is called a "prospect," or the gulch is said to prospect.

THE NECESSITY FOR A TRANS-ALASKAN RAILROAD FROM THE ONLY OPEN-WINTER PORT IN ALASKA NORTH OF THE LYNN CANAL TO THE YUKON VALLEY.

In a report submitted by me to the Honorable Secretary of War in 1899 was one bearing on the practicability of the construction of a railroad from tide-water at Port Valdez to the Yukon River. In this report, Mr. Gillette, my locating engineer, gave in detail the grade, curvature and cost per mile from tide-water to Thomson Pass, the assumption at that time being that the saving in mileage of a main line *via* Thomson Pass, China and Knata Rivers would more than offset the extra cost of tunneling, etc., incident to this pass. Since the discovery, however, of vast deposits of copper in the Wrangell Range and the presence of other minerals in the Brenner and Consena countries, I am in favor of the route *via* Marshall Pass for the following reasons: The gradient over Marshall Pass and down the Taznuna River is nominal; the divide itself is but 1,700 feet in altitude, with an approach to and departure from it that is absolutely devoid of engineering features. This pass will connect the Copper River Valley with tide-water by a grade of not to exceed 1 per cent., is entirely free from glaciers and snow-

slides, is about 47 miles from tide-water at Valdez to the banks of the Copper River, where the Taznuna empties its water into the latter river.

As a temporary measure in opening up the great copper deposits in the Wrangell group of mountains, river boats and scows as a means of transportation for "ore" could be utilized from the mouth of the Taznuna as high up the Copper River as the lower canyon of the Chettyna, and to the rapids about 10 miles below the mouth of the Tonsena.

From the mouth of the Taznuna to Woods Canyon there

Wagon road north of Gakona, 170 miles from Valdez.

is little or no rock-work along the banks of the Copper, the construction work being almost exclusively a side hill cut with few fills. Swinging to the left on reaching Woods Canyon, a short climb of not to exceed 2 per cent. is made for a distance of probably 2 miles, when the summit of an elevation, that I should imagine does not exceed 1,000 feet, is crossed, and the line again drops down to the river. Following up the river a distance of some 18 miles is a possible site for a bridge for a feeder to accommodate the traffic from the Chettyna and the Kotsena mining districts.

Following up the course of the Copper River from this point the work would be featureless, simply grading and filling to the crossing of the Tazlena, where the line would probably leave the Copper River bed, and taking a northeast tangent, pass over a flat, densely timbered plateau to the crossing of the Tanana.

Down this stream some 60 miles, a feeder would reach the end of the Bates Rapids, encountering in construction little or no rock work.

From this point below Bates Rapids, river steamers can ascend and descend from the Yukon at any stage of water. After crossing the Tanana, an easy stream to bridge, the projection of a line is simply a matter of detail in location. From the crossing of the Tanana, south, a 50-mile feeder would connect the main line with the mineral deposits on the headwaters of the White and Tasuna.

From Keystone Canyon to Woods Canyon, tie timber is scarce, the mountain sides being covered almost exclusively with a dense growth of alder. From Woods Canyon to the crossing of the Tasuna, tie timber may be had *en route* in abundance, while in favorite places ample supply of bridge timber can be cut.

As far as the feasibility of a route for the construction of a trans-Alaskan railroad is involved, free from international complications, there is absolutely no question but that there is one route from a seaport that may be entered any day in the year by ocean-going steamers, to connect with a railroad system over an "all-American route" to the Yukon Valley, and that seaport is Valdez.

FEEDERS TO THE MAIN LINE.

If I am correctly informed, the southwest section of the Wrangell group of mountains will, just as soon as transportation facilities offer the opportunity to the miner to move his ore from the mine to the seaboard, furnish thousands of tons of freight per day. I have carefully gone over the ground with both railroad and mining engineers of experience, and am satisfied that the copper deposits of Mount Vlakcburn alone will support 200 miles of road, the

construction of which I place at $14,000 per mile, exclusive of bridging the Copper River.

The Bates River branch would tap the placers of the Keokuk and that portion of the Yukon west of Circle City by the steamers of the river route now established. The White River feeder would tap the mineralized zone of copper and other metals of the northeast district of the Wrangell group of mountains, while the trade of Birch Creek, Forty Mile and other districts, to say nothing of the Chestochena country, would all pay a local tonnage to the main line. I believe that the local tonnage would be of such a volume as to not only earn for such a road a liberal return for the construction bonds, but also, in addition, allow the operators to maintain such a thorough rate of traffic, from the seaboard to the Yukon Valley, as to preclude any attempt to supply that valley *via* a longer and less favored route from the Pacific Coast.

During the subsequent years of 1900 and 1901, followed the construction of the trans-Alaskan military road by me from Port Valdez to the Yukon River, with its docks and bridges, detailed information of which will be found in my reports to the War Department from 1898 to 1901.

It was the construction of this road and the gathering of the information demonstrating the existence of a natural location for a railroad far superior to that through the Canadian Territory, which aided materially the adjustment of the international complications between the United States and Canada relative to the boundary line at the head of the Lynn Canal, the details of which would require volumes.

It is seldom given a man to witness the results of the developing of a country that he has explored, and I take not a little satisfaction in looking back to the earlier stages of my struggle to untangle a small part of this wilderness.

PHYSICAL SECTION.

Stated Meeting, held Thursday, April 23, 1904.

A Proposed Modification of the Perfect Heat-Engine Formula.*

By Louis Illmer, Jr.

According to the first law of thermodynamics, which is based upon the indestructibility of energy, the maximum amount of work which can be produced by means of a heat engine, is equal to the difference between the heat absorbed and the heat discharged by the engine. During transformation an amount of heat equivalent to the work performed must necessarily disappear, hence:

$$W = H_1 - H_2 \qquad (1)$$

where W = heat intercepted and converted into available work by the engine.

H_1 = unstable heat supplied to the engine as measured in foot-pounds.†

H_2 = unstable heat discharged from the engine.

By simple transformation of factors the above equation may also assume the following form:

$$W = \left(1 - \frac{H_2}{H_1}\right) H_1 = \left(\frac{W}{H_1}\right) H_1 = E \,.\, H_1 \qquad (2)$$

where $W \div H_1 = E$ = thermal efficiency, which is the ratio of the thermal equivalent of available work done to the amount of unequalized heat demanded by the engine to produce that work.

The numerical value of the efficiency factor E for specified conditions, cannot actually be determined from equation (2), because the first law of thermodynamics does not state

* Read by title.

† For the sake of mathematical simplicity, heat energy will be measured in foot-pounds throughout this article so as to eliminate the factor for the mechanical equivalent of heat.

definitely, whether or not, the entire amount of heat supplied to a perfect engine can be fully converted into useful work; that is, the first law does not render a fixed value for the factor H_2. The first law simply declares that heat and work are mutually transformable in one definite and constant ratio of conversion and that when heat is transformed into work, the transformation will necessarily take place in such a manner that energy is neither created nor destroyed. As will be shown later, it is actually impossible to completely convert heat into *available* work.

Viewing equation (2) from a mathematical standpoint, it at once becomes evident that there are two unknown factors in a single equation; W is given as a difference of H_1 and H_2, but since the ratio between H_1 and H_2 is not definitely fixed, an infinite number of pairs of values can be found which satisfy the equation. In order to eliminate one of the two unknown factors, another equation must be derived which directly or indirectly fixes the relation between the two independent variables. This required second equation may be regarded as a mathematical statement of the second law of thermodynamics.

The second law is based upon the fact that not all conceivable transformations of energy, which comply with the first law of thermodynamics, can actually occur. Both experience and scientific analysis show clearly that only a certain definite portion of heat energy can be converted into useful work. Heat transformations must necessarily be impelled by some form of instability because only the *unstable* part of heat energy is capable of changing its own condition. Unstable heat represents *potential* difference and is measured by the *unequalized* portion of heat energy in any particular system.

The classification of energy into stable and unstable energy, corresponds, respectively, to Helmholz's bound and free energy. A mathematical factor which measures the instability or intensity head of energy can readily be derived from the following fundamental equation which denotes the equivalence of potential and kinetic energies:

$$w\,h = 1/2\,M\,v^2 \tag{3}$$

where h = height from which body must fall towards the earth in order to acquire a velocity v.

$w = M g$ = weight, which is a measure of the force of gravity acting upon a body whose mass is M.

M = mass or the *quantity* factor of force—mass is the capacity of a body of absorbing and storing force.

g = uniform acceleration of gravity—acceleration is *intensity* factor of force.

$1/2 M v^2$ = kinetic energy.

$w h$ = potential energy.

Equation (3) may also be factored as follows:

$$M \,.\, g h = M \,.\, \frac{v^2}{2} \tag{4}$$

where $g h$ = *intensity* factor of potential energy—an intensity of force multiplied by the distance through which that intensity is capable of acting.

$\frac{v^2}{2}$ = corresponding kinetic intensity.

The above equation shows plainly that energy may be thought of as constituting of two principal factors—a *quantity* or *capacity* factor M and a *quality* or *intensity* factor $g h$ or

$$\frac{v^2}{2}.$$

This important deduction necessarily applies to all forms of energy.

Since heat, considered from the kinetic standpoint, is believed to be a mode of invisible molecular motion, the above deductions as to intensity and extensity must also apply to heat energy. The absolute quantity of sensible heat in a unit volume of any body must then be a function of such molecular motions as produce heat effects. It can be shown that

$$Q = 1/2\, M G^2 = D \,.\, \frac{G^2}{2} \tag{5}$$

where Q = *absolute* sensible heat energy in a unit volume of gas as measured in foot-pounds.

$D = M$ = density of the gas or mass per unit volume.

G^2 = mean square of the molecular velocities as measured from the absolute zero of velocity.

By analogy, it immediately becomes apparent that one-half of the mean square of the molecular velocities is the *absolute* intensity factor of heat energy; accordingly we have:

$$\frac{G^2}{2} = g\,h = C\,T \tag{6}$$

where C = a constant factor of proportionality.

The absolute intensity factor of heat energy T is defined as absolute *temperature.* It measures the absolute thermal potential of heat energy with respect to the absolute zero of temperature, whose numerical value is about 293° C. below atmospheric temperature. The absolute zero represents that fixed point at which all matter is supposed to be totally destitute of heat energy.

Equation (5) also shows that heat energy contains another factor which is independent of temperature, namely, an *extensity* or mass factor, as will be more readily understood by substituting for G^2 as follows:

$$Q = D\,.\left(\frac{G^2}{2}\right) = D\,(C\,T) \tag{7}$$

Temperature as measured in degrees is an arbitrary unit, hence the constant C must be introduced in the above equation so as to bring the temperature factor T into absolute units. Considered rationally, the intensity factor of heat energy ought to be taken as $C\,T$ and not simply as T. In practice, however, it is desirable to combine all constants of proportionality into the extensity factor. By the rearrangement of the constant C, equation (7) finally takes the following form, which applies to both latent and sensible heat energies:

$$Q = (D\,C)\,T = \phi\,.\,T \tag{8}$$

where T = absolute temperature as measured in degrees from the absolute zero.

$D\,C = \phi = \dfrac{Q}{T}$ = a factor proportional to the mass factor of heat energy.

D = density or rational mass factor for heat energy.

Clausius has given the name of *entropy* to the modified thermal extensity factor ϕ; entropy may be considered as a sort of heat weight or heat volume, as shown by Zeuner.

The product of temperature into entropy as a measure of heat energy corresponds to the product of absolute pressure into volume as a measure of the potential energy in a confined gas, or to the product of voltage into current as a measure of electrical energy.

Since the total energy of an isolated system must necessarily remain constant, the numerical value of the product of the quantity into the quality factor cannot in any way be effected by the mutual actions of the forces which compose a confined system. In an isolated system of forces, an increase in one of the energy factors without a corresponding decrease in the other factor would imply either the creation or the destruction of energy. The extensity factor of energy may, however, increase at the expense of the intensity factor, and for certain forms of energy the intensity factor may also increase relative to the extensity factor.

The mutual interchange of the energy factors, relative to each other in both directions, is a property only of the so-called ordinate energy. Energy may exist in either the ordinate or the inordinate form. Ordinate energy is the result of periodic or organized motion, and is at all times under *direct control.* The ordinate forms of kinetic energy, as for instance mechanical or electrical energy, are destined to pass into the "more probable" inordinate or heat form of energy.

The motion which constitutes true *inordinate* energy takes place in all conceivable directions and can be produced only in a medium consisting of infinitely small particles. Inordinate or disorganized motion is *not* directly controllable; due to incessant molecular bombardment, inordinate motion tends to change of itself in such a manner as would equalize the different degrees of intensity of molecular motion.

Such energy inherently tends to increase its extensity factor, but cannot increase its intensity factor at the expense of the extensity factor without compensation of potential.

Sensible heat is naturally a form of inordinate kinetic energy, because due to continuous impact, the molecules of a hot* gas necessarily travel in every conceivable direction. The separate molecules of a hot gas, when in a state of equilibrium, travel in such a manner that the sum of all the component velocities in any one direction is equal to the sum of the component molecular velocities in the direction exactly opposite. The resultant velocity of the center of gravity of a hot gas in equilibrium is therefore equal to zero. Hence, in analyzing motion of this kind, it is necessary to discriminate between the motion of the individual molecules of a hot gas and the motion of the center of gravity of all the molecules. The latter is a resultant motion.

Inordinate motion cannot be retarded directly, but if, by some means, a portion of the molecules of a hot gas can be made to travel continuously in any one definite direction, it will completely convert a corresponding portion of the inordinate energy into the ordinate form, and thereby set the common center of gravity of the molecules in motion. By interposing a resistance to such progressive rectilinear motion, the mechanical energy of the moving mass of gas, now under control, can readily be transferred to other bodies. This primitive process of transformation is one of the simplest methods for converting the irregular or zig-zag motions of heat ino mechanical energy.

We have no direct control over the direction of disorganized molecular motions of a hot gas which is confined to a definite volume; inordinate motion can, however, be controlled indirectly by *change* of volume. Furthermore, only those gases which are in a state of unstable equilibrium are capable of changing their own volume. Hence, since instability measures the power with which a gas tends to expand, inordinate molecular motions can simply be made to rectify

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* Throughout this article the term "hot" gas refers especially to one possessing a temperature head with respect to the atmosphere.

themselves in direct proportion to the *unequalized* heat energy residing in the working fluid.

For the conversion of inordinate into ordinate energy, and subsequently for the conversion of ordinate energy into work, we need consider merely that portion of the inordinate energy which is under control; in any case the controllable portion of energy is equal to the *unequalized* portion of heat energy of the system as determined by a *relative* standard of measurement. For heat energy transformations, the mean atmospheric temperature should be taken as the standard by which to measure relative potential or temperature heads. The thermal capacity of the atmosphere may be regarded as infinitely large when compared with that of a limited quantity of isolated working substance. The effect of this assumption is that all thermal energy tends to approach the atmospheric temperature.

When the unequalized intensities in the different parts of a heat-energy system finally become perfectly uniform throughout, such heat energy must forever remain in the equalized state unless the system as a whole still possesses a thermal *potential* with respect to some external system. Completely equalized heat energy is said to be in a state of *stable* equilibrium, and its availability is permanently lost. In analyzing thermal phenomena, it is necessary, therefore, to distinguish carefully between an absolute and a relative potential head.

The work which a hot gas can be made to do is directly proportional to the degree to which molecular motions can be absorbed by converting a portion of the heat into another form of energy. As has already been stated, inordinate molecular motion (heat energy) can be controlled indirectly when a temperature head is available; not until the zero of reference could be maintained at the absolute zero, *i. e.*, about 500° F. below atmospheric temperature, would it be possible to fully convert the entire or absolute heat residing in a hot gas into useful work. Under these conditions all molecules could be brought to a state of rest.

The corresponding mechanical analogy is quite simple. The motion which we ordinarily consider in equations for

mechanical energy is actually a relative and not an absolute motion. Due to the rotation of the earth, all bodies on its face really have an exceedingly high velocity with respect to an absolutely stationary body in space; in consequence, the absolute velocity of any body on the earth's surface is actually very much greater than that due to its measurable relative motion.

It is quite as impossible to convert the entire or absolute heat energy of a hot working substance into work when the temperature of reference is that of the atmosphere, as it is to utilize the entire or absolute motion of a body without being in a position of absolute rest in space.

When, however, the atmospheric temperature is considered as an arbitrary zero of reference for relative temperatures, in the same way that the motion of the earth's surface is ordinarily assumed to represent the state of so-called rest for mechanical motion, then the *unequalized* heat energy residing in any working substance can be completely transformed into work for exactly the same reason that the available mechanical energy of a body can be fully transformed into heat.

At atmospheric temperature, a working fluid contains within itself a certain amount of potential and kinetic energy with respect to the *absolute* zero temperature; such intrinsic thermal energy cannot possibly be converted into available work because the working substance possesses no relative potential with respect to the atmospheric temperature. Accordingly, the equalized or intrinsic thermal energy of a working fluid cannot in any way affect the final efficiency of a heat transformation.

In order to find the proportion of heat which can actually be converted into work, it is positively necessary to separate the absolute heat into stable and unstable energy.

The unequalized portion of the absolute heat residing in a working substance can readily be determined by transferring the zero of reference from the absolute zero to atmospheric temperature. It is essential that the mean atmospheric temperature be taken as the zero of reference; any other temperature would not completely separate the

absolute heat energy into equalized and unequalized heat energy.

According to the foregoing discussion we have:

$$H = Q - Q_0 \tag{9}$$

where H = the *unequalized* heat energy in a unit weight of working fluid as measured from the mean atmospheric temperature.

Q* = total or absolute heat energy in a unit weight of working substance; it includes both sensible and latent heats.

Q_0 = intrinsic or stable heat energy in a unit weight of working substance at atmospheric temperature. The numerical value of the constant Q_0 is ordinarily indeterminable.

Transforming and substituting the value of Q as given by equation (8),

$$Q = \phi \,.\, T = H + Q_0 \tag{10}$$

Differentiating, we have:

$$d\,Q = \phi \,.\, d\,T + T \,.\, d\,\phi = d\,H + O$$

Confining this equation to *unit* weight of working substance, the extensity factor ϕ will be a constant, *i.e.*, $d\,\phi = O$, and, therefore, the above equation reduces to:

$$d\,H = \phi \,.\, d\,T.$$

Finally, integrating between the limits of temperature T_1 and T_0, we have:

$$H = \phi\,(T_1 - T_0) = \phi \,.\, t_1 \tag{11}$$

where T_0 = atmospheric temperature as measured on the absolute scale

$(T_1 - T_0) = t_1$ = temperature head of the working substance as measured with respect to atmospheric temperature.

The quantity of available heat, H, residing in a unit weight of working substance, is directly proportional to the

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* The quantity Q must not be confounded with the heating value of a fuel. The heating value of coal, for instance, measures the available potential or unstable energy in a pound of coal; it should properly be designated by H.

temperature *head* existing between such a hot body and the surrounding atmosphere.

Carnot, the originator of the thermodynamic cycle, states this principle in a somewhat different form:*

"Heat alone is not sufficient to give birth to impelling power; it is necessary that there shall be cold; without it heat is useless."

The one essential requirement for the conversion of heat into work is initial temperature difference or thermal instability. When the temperature head of thermal energy finally becomes equal to zero, so that heat can no longer be transferred to colder surrounding bodies, *i. e.*, the atmosphere, such heat must remain in the form of heat, and cannot further serve for the production of useful work. In this condition the fully equalized heat energy has reached a state of stable equilibrium, and no longer tends to change its form.

Having shown that only the unstable portion of the total energy Q can be converted into work, we must now determine what portion of such mechanical energy can actually be converted into *useful* work. A part of the absolute work of expansion is necessarily absorbed and rendered latent in displacing the atmosphere.

Ordinarily the thermodynamic formulæ for work done during expansion, do not discriminate between useful and the unavailable displacement work, but simply measure total or absolute work. The net or available work of expansion can readily be found as follows: Let P denote the total absolute pressure in pounds of the gas confined within a cylinder and let P_0 denote the total absolute pressure in pounds of the atmosphere resisting the piston motion; then,

$$d\,W = (P - P_0)\,d\,V \tag{12}$$

where W = available or resultant positive work of expansion as measured in foot-pounds.

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* Carnot: "Reflections on the Motive Power of Heat." Translated from the French by Dr. R. H. Thurston.

$dV =$ change in volume of the working substance as measured in cubic feet.

$P \cdot dV \doteq$ total or absolute work of expansion as measured in foot-pounds.

$P_0 \cdot dV =$ unavailable or negative work of expansion as measured in foot-pounds.

The effective work produced by a perfect gas when expanding from an initial volume V_1, to a larger volume V_2, can be determined by substituting the characteristic value for P in the above equation.

For isothermal expansion of a perfect gas $PV = C =$ a constant, hence ;

$$W = C \int_1^2 \frac{dV}{v} - Po \int_1^2 dV$$

$$= C \log._e \frac{v_2}{v_1} - Po\ (v_2 - v_1)$$

$$\doteq C \log._e \frac{P_1}{P_2} - Po\ (v_2 - v_1 \qquad (13)$$

where $W =$ external work which would actually have to be done upon the gas in order to re-establish the original volume v_1 by means of isothermal compression.

$C \log._e \frac{v_2}{v_1} = C \log._r =$ total or absolute work of isothermal expansion.

$r = \frac{v_2}{v_1} =$ ratio of expansion.

$Po\,(v_2 - v_1) =$ latent work done in displacing the atmosphere. This stored work may be refunded to the working fluid in the form of sensible heat during compression.

Since both the temperature and the mass factor of the working substance remain constant during isothermal expansion, the entire unstable heat supplied to a perfect gas is fully converted into work, *i. e.*

$$H = C \log._e r = W + Po\,(V_2 - V_1) \qquad (14)$$

where $H =$ the uneqalized heat supplied to the working substance as measured in foot-pounds.

Equation (14) shows that only a certain portion W of the unstable heat H can be converted into useful or *available* work. The production of a large proportion of available work from a given amount of unstable heat, requires a relative reduction in the displacement work. This condition is satisfied when a comparatively high mean effective pressure of expansion is maintained with relation to the atmospheric pressure.

If, on the contrary, expansion is unduly extended so as to allow the pressure of expansion to fall below atmospheric pressure, the negative displacement work will exceed the corresponding positive work of expansion and accordingly result in the predominance of negative work, as shown by the shaded area B, in *Fig. 1.* No available work can be secured from heat energy by expanding below atmospheric pressure when the resisting pressure is that of the atmosphere. This important principle can be incorporated in equation (13) by limiting the final pressure P_2 to the atmospheric pressure P_0, thus,

$$W = C \log._e \frac{P_1}{P_0} - P_0 (V_2 - V_1) \qquad (15)$$

This equation represents the greatest amount of *available* work which can be produced by direct isothermal expansion of a perfect gas whose initial pressure and volume are P_1 and V_1, respectively. Equation (15) shows, furthermore, that it is impossible to *fully* convert heat into effective work. In so far as this deduction is based upon the assumption that $P V = C$ during isothermal expansion, it applies to the perfect gas only.

It can be shown, however, that a similar conclusion also applies to the imperfect gases. But in order to eliminate the indeterminable amount of energy, which is demanded to separate the molecules of an imperfect gas during expansion, a rigorous proof of the corresponding analysis requires the adaptation of a series of cyclic processes. A cycle permits the successive re-establishment of the initial conditions of temperature, pressure and volume of the working substance by means of alternate expansion and contraction. All the work produced by a cycle of this kind will be due

solely to the heat supplied to the engine and is not in any way dependent upon the intrinsic heat energy residing in the working fluid.

Before deducing formulæ for the different thermodynamic cycles, it is necessary to ascertain the essential conditions for the realization of *maximum* efficiency.

Every heat energy transformation must be impelled by a potential difference; conversely, every heat energy change which can take place of itself is capable of rendering a definite amount of work when properly utilized. For perfect transformation, the unstable heat energy lost during transformation must be fully recovered by available energy of another form so as to maintain the instability of the system constant throughout the transformation.

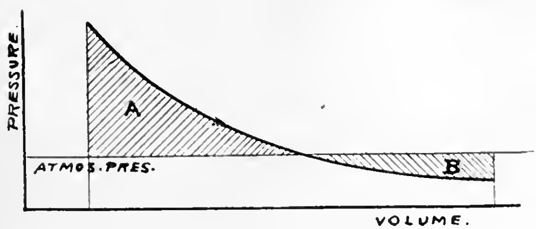

FIG 1.

Carnot summarizes these ideas in the following significant quotation:

"Since every re-establishment of equilibrium may be the cause of the production of motive power, every re-establishment of equilibrium which shall be accomplished without the production of this power should be considered as an actual loss. Reciprocally, every time this condition is fulfilled, the maximum will be attained."

In other words, the above thermodynamic principle implies a perfectly reversible process or cycle such that the initial physical and thermal conditions, which the working substance possessed before transforming a given portion of its heat into work, can be completely re-established.

A certain amount of available motive power will be permanently lost whenever the source of heat is wholly, or even

partially, allowed to come in direct contact with the refrigerator. Such a cycle cannot, therefore, be perfectly reversible. The primary theoretical requirement for a cycle of maximum efficiency is that the working substance must have an infinitesimal difference of temperature from that of the source while receiving heat and a similar difference of temperature from that of the refrigerator while discharging heat. Consequently the temperature of the working fluid must be reduced by some means from T_1, the temperature of the source, to T_2, the temperature of the refrigerator, so that the waste heat can be discharged without loss of unstable energy.

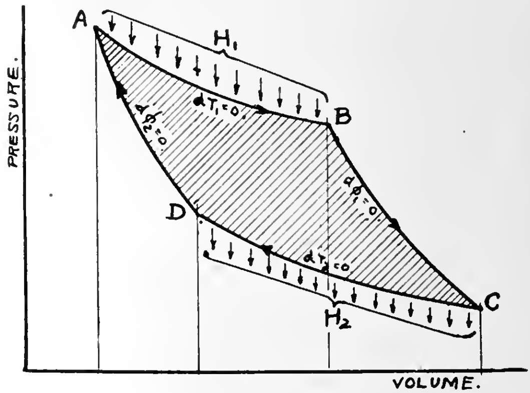

FIG. 2.

It can readily be proved that the work produced by a perfect heat engine is due simply to the difference of the works represented by the isothermal lines. It is immaterial, theoretically, in which manner the temperature of the working substance is reduced from the temperature T_1 to T_2, provided only that precisely the same quantity of energy is refunded to the working fluid while raising its temperature as was previously stored while lowering it.

This process of temperature reduction may involve the storage of heat in the form of work by means of adiabatic expansion, as in the Carnot cycle; or it may involve the storage of heat energy in the form of heat by means of a regenerator, as in the Stirling cycle; and for the more com-

plicated case, as in the Ericsson cycle, a combination of the two methods may be employed. Theoretically, the thermal efficiency of all three cycles is the same.

The perfect cycle consists essentially of a source of heat, from which heat energy is abstracted by the working substance at one constant high temperature, and a refrigerator into which waste heat may be rejected at one constant low temperature. The Carnot cycle is bounded by a set of isothermal and adiabatic lines and is, therefore, a perfectly reversible cycle.

Referring to *Fig. 2*, heat is admitted into the engine cylinder, at a temperature T_1, along the isothermal line $A\ B$. The temperature of the gas is reduced to the lower limit T_2 by means of adiabatic expansion along the line $B\ C$. The waste heat is discharged into the refrigerator along the isothermal line $C\ D$. The cycle is then completed by elevating the temperature of the working fluid by means of adiabatic compression along the line $D\ A$ so as to restore the initial temperature.

Formulæ for the Carnot Cycle.

Range of temperature $= T_1 - T_2$.

Unequalized heat supplied:

Along $A\ B$ at constant temperature T_1.

$$= H_{ab} = R\ T_1 \log._e \frac{V_b}{V_a} \tag{16}$$

Unequalized heat discharged:

Along $C\ D$ at constant temperature T_2.

$$= H_{cd} = R\ T_2 \log._e \frac{V_c}{V_d} \tag{17}$$

Adiabatic expansion along $B\ C$; $(H_{bc} = 0)$;
Adiabatic compression along $D\ A$; $(H_{da} = 0)$.

Production of Available Work of Expansion:

Along isothermal $A\ B$

$$= W_{ab} = P_a V_a \log._e \frac{V_b}{V} - P_0(V_b - V_a)$$

Along adiabatic $B\ C$

$$= W_{bc} = K_v(T_b - T_c) - P_0(V_c - V_b).$$

Consumption of Available Work During Compression:

Along isothermal $C\ D$

$$= W_{cd} = P_c V_c \log._e \frac{V_c}{V_d} - P_o(V_c - V_d)$$

Along adiabatic $D\ A$

$$= W_{da} = K_v(T_a - T_d) - P_o(V_d - V_a).$$

Since the difference of temperature between the two isothermal lines is constant, we have,

$$(T_b - T_c) = (T_a - T_d) = (T_1 - T_2)$$

also,

$$\left(\frac{V_d}{V_a}\right)^{k-1} = \frac{T_1}{T_2} = \left(\frac{V_c}{V_b}\right)^{k-1}$$

therefore,

$$\frac{V_b}{V_a} = \frac{V_c}{V_d} = r = \text{ratio of expansion.}$$

These qualities show that the work of adiabatic expansion is equal to work of adiabatic compression. The displacement work is eliminated by subtraction and hence the formula for the resultant *available* work takes the following simplified form:

$$W = W_{ab} + W_{bc} - W_{cd} - W_{ad}$$

$$= P_a V_a \log._e \frac{V_b}{V_a} - P_c V_c \log._e \frac{V_c}{V_d}$$

$$= R(T_1 - T_2) \log._e r = H_{ab} - H_{cd}. \quad (18)$$

Finally, the theoratical thermal efficiency of the perfect heat engine is,

$$E = \frac{W}{H_{ab}} = \frac{T_1 - T_2}{T_1} = 1 - \frac{T_2}{T_1} \quad (19)$$

where E = thermodynamic efficiency of the perfect heat engine—perfect in the sense that no other heat engine can be more efficient thermally when working between the temperature limits T_1 and T_2.

T_1 = absolute temperature of the source of heat.

T_2 = absolute temperature of the refrigerator.

$\frac{T_2}{T_1}$ = ratio of the unequalized heat discharged to the unequalized heat supplied to the engine; it represents the fractional loss of potential during transformation.

During expansion, the heat supplied to the engine is only partially converted into available work, but during compression the consumption of available work apparently more than produces its equivalent of heat, because the latent displacement work also assists in compressing the gas.

The restoration, during compression, of the displacement work in the form of heat energy, increases the heat discharged from the engine; this, in turn, reduces the thermal efficiency of the cycle. The latent displacement work is really similar in its effects upon thermal efficiency to re-evaporation in the steam engine. Consequently, to produce a certain amount of available work by means of a perfect engine, it is necessary to add not only enough heat to produce the available work W, but also an additional amount of heat sufficient to compensate for the inapplicable displacement work. The characteristic manner in which the latent displacement work increases the discharged heat H_2, involves a permanent loss of availability of motive power and the law of dissipation of energy follows as a natural consequence.

As the stored displacement work cannot possibly be recovered in the form of available work, the efficiency of conversion of heat into available work can never reach unity. For maximum efficiency, we should endeavor to retain a maximum amount of available work of expansion by restoring the initial conditions of the working substance with a mimimum expenditure of compression work. At first sight it appears as though a cycle, in which heat is discharged at constant pressure, may be more efficient than one in which heat is discharged at constant temperature; a little reflection will show, however, that when heat is discharged at a constant pressure, it suffers a useless temper-

ature drop, which is contrary to the condition of maximum efficiency.

To produce the maximum amount of work, all the heat must be absorbed by the working fluid at the highest temperature possible, and in order to reduce the heat discharged to a minimum, all the heat must be abstracted from the working substance at the lowest temperature possible. The highest temperature available is limited by conditions of combustion, while the lowest temperature is limited to atmospheric temperature.

If expansion were continued to such an extent as to reduce the temperature of the working substance below that of the

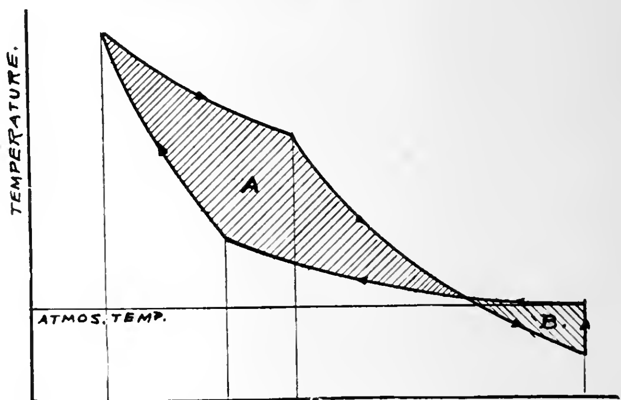

FIG. 3.

atmosphere, it would be impossible to discharge the waste heat from the engine directly into the atmosphere, because such heat would possess no positive temperature head with respect to the atmospheric temperature. In case the working substance is heated at the termination of expansion, so as to acquire the temperature of the atmosphere, before isothermal compression begins, as shown in *Fig. 3*, the effective work done will be equal to the difference of the positive area *A* and the negative area *B*. Unduly extended expansion, therefore, increases the heat discharged into the refrigerator and actually involves a loss of effective work. Increased expansion necessarily results in

decreased efficiency when the continued expansion reduces the temperature of the working fluid below that of the atmosphere.

As shown by equation (17), the unstable heat discharged from an engine is equal to the product of the absolute temperature of discharge T_2 into the natural logarithm of the ratio of expansion r. For insufficient expansion, the factor H_2 will be large on account of the excessive value of the factor T_2. If, on the contrary, the expansion is increased unduly so as to reduce either the temperature or the pressure of the working substance below that of the atmosphere, the heat discharged from the engine will likewise be larger than necessary on account of the enlarged value of the factor r.

This analysis shows clearly that the factor H_2 can never be reduced to zero; it has a certain definite minimum value, which is given by the following equation:

$$H_{2\,0} = R\ T_0 \log. \frac{P_1}{P_0}$$

When the discharged heat has been reduced to the atmospheric temperature, it has reached the equalized or stable state and cannot further be utilized for the production of useful work. Consequently, the maximum amount of *available* work which can possibly be produced for a given amount of unstable heat H_1, by any cycle whatsoever, is,

$$W_{\max} = H_1 - H_{2\,0} = R\,(T_1 - T_0) \log._e \frac{P_1}{P_0} \qquad (20)$$

where T_1 = absolute temperature of the source of heat.

T_0 = mean absolute temperature of the atmosphere.

$H_1 = R\ T_1 \log._e \frac{P_1}{P_0}$ = amount of unstable heat supplied during isothermal expansion.

$H_{2\,0} = R\ T_0 \log._e \frac{P_1}{P_0}$ = the minimum amount of heat which can be discharged into the refrigerator (*i. e.*, atmosphere) for given conditions of transformation.

The corresponding thermodynamic efficiency is,

$$E_{\max} = \frac{W_{\max}}{H_1} = \frac{T_1 - T_0}{T_1} \tag{21}$$

In this formula, the factor $(T_1 - T_0)$ is the temperature *head* which the working substance possessed initially with respect to the atmospheric temperature; hence, equation (21) may take the final form:

$$E_{\max} = \frac{t_1}{T_1} \tag{22}$$

where $E_{\max}$ = the greatest fractional part of a given amount of unstable heat energy at a given absolute temperature T_1, which can possibly be converted into useful work.

$t_1 = T_1 - T_0$ = temperature head of the source of heat with respect to the atmospheric temperature.

The above equation, which may be considered as the mathematical statement of the second law of thermodynamics, is the relation required to eliminate one of the two independent variables of equation (1).

A complete definition of the second law of thermodynamics may be stated as follows:

Every heat-energy transformation must be impelled by a difference of thermal potential. Such difference of potential is proportional to the temperature head, which, in turn, measures the unstable heat energy residing in a unit weight of working fluid. Only the *unequalized* portion of heat energy can be converted into work, and of such work only a fractional part can be utilized as *available* motive power. The greatest possible efficiency with which unstable heat can be transformed into available work is equal to the ratio of the temperature head of the working substance to its corresponding absolute temperature.

If, instead of expanding down to atmospheric temperature, heat is discharged from the engine at an absolute temperature T_2, which is higher than T_0, the maximum efficiency of the cycle will be that of the Carnot, as shown by

equation (19). In terms of temperature heads, the efficiency formula can also be written in the following form:

$$E = \frac{t_1 - t_2}{T_1} \tag{23}$$

where t_1 = temperature head, with respect to the mean atmospheric temperature, at which all heat has been supplied to the engine.

t_2 = temperature head with which all the heat has been discharged from the engine.

$t_1 - t_2$ = effective temperature head of the working substance.

$\frac{t_1 - t_2}{t_1}$ = measure of the relative waste of potential as compared with the efficiency E_{max}.

The thermal efficiency factor E determines, relatively, the greatest amount of *effective* rectification of the unstable heat motion which can be produced for given conditions of transformation. It is immaterial by what means this process of rectification is accomplished.

Equation (23), which is really a combination of the first and second laws of thermodynamics, shows clearly that when no temperature *head* is available in the working substance, it is impossible to produce useful work. This modified form of the Carnot efficiency formula, which the writer proposes, is based upon the principle of unstable energy as the essential requirement for the production of useful work; in this respect it is essentially different from the derivation of the Carnot efficiency formula, which is deduced for total or absolute temperature heads, and hence does not discriminate between stable and unstable heat energy.

The Carnot formula leads one to infer, fallaciously, that even when heat is discharged from an engine at atmospheric temperature, such heat still contains available potential, while, as has been proved, the available unstable heat energy of the working substance has already been fully utilized. The proposed modification does not become identified with the efficiency formula for the perfect heat engine until the essential factor of thermal instability is introduced in terms of a temperature head. In the writer's opinion,

the insertion of this factor into the Carnot efficiency formula and a careful discrimination between equalized and unequalized heat will undoubtedly eliminate much of the ambiguity which is frequently encountered in interpreting fundamental thermodynamic principles.

In a thermodynamic cycle, every temperature change which is not the effect of change of volume or chemical action, is necessarily due to the direct passage of heat from a hot into a colder body, and represents a loss of available motive power. When this dissipated heat is allowed to pass into unisolated atmosphere, it invariably results in a complete loss of thermal potential. Such changes are irreversible, inasmuch as a certain portion of the initial amount of unstable heat permanently loses its relative temperature head. A cycle is not reversible unless the entire unstable energy in a unit weight of working fluid remains under complete control.

The availability of heat energy will, of course, be permanently decreased by every energy change unless the intensity head lost by one form or mode of energy is fully compensated by the appearance of an equivalent available intensity *head* of another form or mode of energy. Such an ideal transformation is possible only in a perfectly *isolated* system. All the previously discussed perfect transformations presuppose that it is practicable to isolate a system in such a manner as to absolutely prevent exchange of energy with external systems.

In practice it is practically impossible to isolate kinetic energy completely because the unequalized portion of energy is readily affected by certain irreversible processes, such as conduction, radiation, etc., which we cannot adequately control.

In regard to isolation, the transformation into work of a low thermal intensity possesses several important thermodynamic advantages, as can be proved by comparing the actual indicator card areas of the steam and gas engines with their respective ideal card areas. The ratio for the low intensity steam engine is considerably greater than that of the gas engine which works with a high intensity head.

This unfavorable comparison as regards the gas engine is due principally to the necessity of artificially cooling the cylinder walls.

Eventually the thermal loss resulting from the water jacket in the gas engine will, no doubt, be considerably reduced. This difficult problem could be partially solved by shielding the cold metallic walls during combustion, so as to prevent the instability of explosion from getting away. For practical reasons the isolating medium should not consist of a solid substance, but rather of an inert portion of the working substance itself; that is, a concentric or annular charge of pure air should be made to surround the explosive mixture during combustion. This suggestion is in accordance with the tenor of the above thermodynamic discussion of thermal instability, and if the idea could be fully applied in practice it would unquestionably result in a decided improvement in economy of internal combustion motors.

It is radically wrong to adopt very high temperature heads for heat-engine cycles without at the same time providing a correspondingly perfect system of isolation for the working substance. It is true that the initial temperature head should be made as high as possible in order to realize maximum thermal efficiency, because relatively it reduces the amount of heat discharged, but this principle should not be carried to the point where we almost completely lose control of the process of transformation. The present tendency to use excessively high temperature in the gas engine is in a large measure due to blindly following Carnot's law of thermal efficiency; according to this law the thermal efficiency can only reach a maximum when the temperature of the source T_1 reaches its greatest possible value. Such a distractive treatment of the real heat-engine problem often leads to entirely wrong conclusions. Instead, thermal efficiency for the real heat engine ought to be measured by means of the following modified formula, because it permits far more comprehensive conclusions to be drawn regarding the requirements of the real heat-engine cycle.

In analyzing the real heat-engine cycle it is necessary to

take into account the isolation factor. This very important factor has heretofore been entirely overlooked in theoretical discussions. Actually, the resultant efficiency of a heat-engine cycle may be thought of as consisting of two opposing theoretical factors, as shown by the following equation, which readily leads to a rational solution of the heat-engine problem:

$$E_i = E_t \quad . \quad E_c = \frac{t_1 - t_2}{T_1} \quad . \quad E_c \tag{24}$$

where E_i = theoretical indicated efficiency of the cycle.
E_t = thermodynamic efficiency of the perfect heat engine.
E_c = efficiency of isolation; this factor varies inversely with the initial temperature heat t_1.

In the final form, the heat-engine formula discloses the fact that the maximum resultant efficiency of a thermodynamic cycle can be obtained only when the product of the thermal efficiency E_t into the efficiency of isolation E_c reaches its greatest possible numerical value. Since these factors vary in opposite directions, there is a certain maximum attainable efficiency for every type of heat-engine cycle; this resultant efficiency E_i does not become a maximum for maximum effective temperature head $(t_1—t_2)$ unless the isolation of the working substance is perfect, *i. e.*, when $E_c = 1$.

The more nearly perfect the isolation, the more closely may the theoretically possible transformations be verified. The introduction of the isolation factor places the theoretical discussion of the heat-engine cycle for high temperature heads upon a sound basis, and so tends to diminish the discrepancies which still exist between the theoretical and practical heat-engine problem. In so far as no real system can be completely isolated, the essential factor of isolation ought not to be omitted from the efficiency formulæ for heat engines. The isolation or condensation factor is really the principal component of the so-called "experience or card factor" which must be applied to all deductions from theoretical indicator cards so as to make the theoretical cal-

culations for fuel consumption, etc., conform with those actually obtained in practice.

According to the above principle, all attempts to increase the thermal intensity factor of a gas-engine cycle at the expense of the isolation factor must necessarily result in a loss of indicated efficiency. Equation (24) shows clearly that the efficiency of the present types of internal combustion motors cannot be radically improved so long as the high thermal potential resulting from combustion is permitted to come in direct contact with the comparatively cold cylinder walls. A substantial reduction in the jacket loss of the existing gas engines can be secured only by suppressing this heat waste by means of the aforesaid method of thin annular charges of cool fresh air or its equivalent.

The successful application of the isolating charges of pure air depends upon devising simple means which would control the distorting effects of the intense conduction currents, so as to insure and maintain a comparatively thin but effective stratification during explosion; otherwise, the cylinder dimensions and friction of the engine would be increased without realizing a corresponding net gain in efficiency. The sudden expansion of the explosive charge during combustion increases the temperature of the surrounding layer of inert air to a certain extent by mechanical air, and so prevents an excessive rise of the combustion temperature. With increased isolation of the working substance the ratio of expansion of the engine would have to be increased considerably, in order that the decreased jacket loss would not be accompanied by an increased exhaust loss.

Besides the theoretical advantages of increased isolation, the concentric stratum of air adjacent to the cylinder wall has the additional practical advantage of facilitating the lubrication of the sliding parts. In fact, the proposed layer of isolating air largely overcomes many of the disadvantages of the water jacket without forfeiting its indispensable practical advantages. The foregoing suggestions regarding the improvement of the isolation factor indicate the lines along which further increase in the economy of the internal combustion motor is to be sought.

Correspondence.

THE INTERNATIONAL CONGRESS OF ARTS AND SCIENCES, SEPTEMBER 19–25, 1904.

The scope of this Congress was very broad, as it was the purpose of its originators to collate the best and most recent data in the entire field of human knowledge, by means of specialists well versed in their particular fields of research, and to submit a symposium of their papers to the Congress for presentation in permanent form.

Thus, while the industries, resources and products of all the nations of the earth were assembled in visible and material forms, revealing their physical properties, it was deemed necessary to supplement these by the psychological elements, which are, in fact, the basis of the wonderful inventions and products of this generation.

To this end a broad classification of subject-matter was carefully prepared by the Administrative Board, composed of Dr. Howard J. Rogers, Director of the Congress; Drs. Nicholas M. Butler, Wm. P. Harper, R. H. Jesse, Henry S. Pritchett, Herbert Putnam and F. J. V. Skiff.

It is not possible to summarize the ramifications of the various divisions of this scheme further than to state that the Normative Sciences, embracing:

	Groups.
Philosophy and mathematics were subdivided into	9
Historical sciences, political and economic history into	32
Physical science, physics, chemistry, astronomy, the earth, biology and anthropology into	31
Mental science, psychology and sociology into	6
Utilitarian sciences, medicine, technology, economics into	24
Social regulation, politics, jurisprudence, social science into	14
Social culture, education and religion into	11

Making 127 subdivisions, in each of which two distinguished specialists were selected to prepare and present in person (*a*) "The Fundamental Conceptions and Methods" of his theme; (*b*) "The Progress during the Last Century." These were followed by miscellaneous ten-minute papers and discussions.

It is needless to add that the representation gathered from all quarters of the globe constituted an imposing spectacle as they were assembled as the guests of the Management of the Exposition in the Swiss Pavilion, where President Francis entertained over 700 of them at dinner.

The program of the Congress was admirably executed by its officers, Prof. Simon Newcomb, President; Dr. Hugo Muensterberg, Vice-President; Prof. Albion W. Small, Honorary Vice-President; Right Hon. Jas. Bryce, M.P., M. Gaston Darboux, Wilhelm Waldeyer, Oskar Backlund, Theodore Escherick, Attilio Brunialti.

The Executive Secretary was Dr. L. O. Howard, the Permanent Secretary of the American Association for the Advancement of Science. No reference can be made to the personnel of this Congress, or the subject-matter of the

papers, without seeming to make invidious distinctions. The papers and discussions, it is expected, will be published at the close of the Exposition as a part of its proceedings.

LEWIS M. HAUPT.

PHILADELPHIA, October 7, 1904.

THE INTERNATIONAL ENGINEERING CONGRESS, LOUISIANA PURCHASE EXPOSITION.

Following in the wake of the Congress of Arts and Sciences came that of the Engineering Profession. This was likewise a representative gathering of men of great executive and administrative ability from all corners of the earth.

The papers and subjects presented for discussion were classified under the general topics of: (*a*) Harbors; Waterways, Natural and Artificial; Traffic, Dredges, Wharves and Piers, presided over by Alfred Noble. (*b*) Water Supply, Sewage Disposal, Municipal Refuse, under J. J. R. Croes. (*c*) Railroad Terminals, Underground Railroads, Live Load for Bridges, Ventilation of Tunnels, under Robert Moore Stearns. (*d*) Manufacture of Steel and Cement, Concrete, Tests of Materials, under F. P. Stearns. (*e*) Water for Steam, Turbines, Rolling Stock, Elevators, Pumps, under Wm. Metcalf. (*f*) Electricity, under Frank J. Sprague. (*g*) Military, Naval and Marine, Lighthouses, Docks, under Wm. P. Craighill. (*h*) Miscellaneous, Irrigation, Highways, Deep Foundations, Mining, Education, Surveying, under Octave Chanute.

The sessions of the Congress extended from Monday, October 3d, to the 8th, and up to its close there were over 850 registrations. The countries represented include the most progressive nations of the earth, and the problems submitted for discussion covered those relating to the more rapid development of international commerce; the increasing demands for cheaper and more abundant power; the necessity for greater sanitary precautions in large cities; the latest improvements in use of structural materials, especially in steel and concrete, and the demand for larger internal waterways for domestic commerce.

The foreign delegates were the guests of the American Society of Civil Engineers, over which Charles Hermany presides.

The papers will be published as a part of the proceedings of the American Society, and will form an invaluable addition to the record of the century.

PHILADELPHIA, October 7, 1904. LEWIS M. HAUPT.

Notes and Comments.

ASBESTOS PRODUCTION.

According to a report made to the Geological Survey by Dr. Joseph Hyde Pratt, the production of asbestos in the United States in 1903 was only 874 short tons, which compares with 1,005 short tons in 1902. Most of the asbestos reported in 1903 came from the mine at Sall Mountain in White County, Ga., but small quantities were mined at Dalton in Berkshire County, Mass., and near New Hartford in Connecticut. Some deposits near Lowell, Vt., are being explored.

PYRRHOTITE AS A SOURCE OF SULPHUR.

According to Ernst A. Sjöstedt, in a paper read before the Canadian Mining Institute, March, 1904, the manufacture of sulphuric acid from pyrrhotite has been successfully accomplished at Sault Ste. Marie. The ore (from Sudbury) contains 15 to 20 per cent. sulphur, 1 to 3 per cent. nickel, and 0·5 to 2 per cent. copper. The ore is sorted into two classes; one high in copper and low in sulphur; the other low in copper and high in sulphur. The former is smelted to matte in the ordinary way; the latter is sent to the acid plant. It averages about 28 per cent. S, 3 per cent. Ni, 0·5 per cent. Cu and 50 per cent. Fe. The roasting is done in a modification of the Herreshoff furnace, the external cylindrical form being abandoned and four shafts constructed in a block, loss of heat by radiation being thus reduced. In this way, and with other means to conserve heat, designed in accordance with good engineering practice, satisfactory results have been obtained. The furnaces are constructed in muffle-form, arranged for gas-firing, but improvements in the details and increase in experience enabled that to be dispensed with, and ore as low as 20 to 25 per cent. S has been burned down to 1 to 3 per cent. S, producing a gas with 6 to 10 per cent. SO_2, without the use of any extraneous fuel. The plant comprises four blocks of kilns with an aggregate capacity of 40 tons of ore per day, and, up to the time of writing, had burned 10,000 tons of pyrrhotite and 3,000 tons of pyrites. The experience is very valuble, showing how a poor sulphur ore can be almost completely burned without extraneous fuel when proper means are taken to avoid loss of heat in excess air, by radiation and otherwise.—*Engineering and Mining Journal.*

RADIUM AND THE DIAMOND.

In the course of some experiments concerning the effect of the emanations from radium upon diamonds, Sir William Crookes made a curious discovery. When a diamond was placed in the path of the radiations it was converted from the carbon crystal into the common form of graphite, while in addition its color was quite changed. As a result of this strange metamorphosis Sir William Crookes suggests that the radium rays may prove of great commercial value to the jeweler, since by this means diamonds which are of an indifferent and defective color may be appreciably increased in their commercial value by treatment under the radium rays. He also observed that prolonged action of the radium also increased the intensity of the pale-colored gems.—*Scientific American.*

STATISTICS OF PETROLEUM.

It is not yet half a century since Col. Drake discovered petroleum on the waters of Oil Creek, near Titusville, Pa. The total production of crude petroleum from 1859 to 1902—forty-three years—has been no less than 1,165,280,727 barrels. Of this output, Pennsylvania and New York contributed 53·9 per cent.; Ohio, 24·3 per cent.; West Virginia, 11·3 per cent.; Indiana, 3·9 per cent.; California, 3·6 per cent.; Texas, 2·1 per cent.; leaving 11 per cent. to be supplied by Kansas, Colorado, Louisiana, Illinois, Missouri, Indian Territory, Wyoming, Michigan and Oklahoma.

THE PRODUCTION OF FLINT AND FELDSPAR IN 1903.

The production of flint or quartz in 1903 amounted to 40,046 short tons of crude flint, valued at $38,736 and 15,187 short tons of ground flint, valued at $118,211, a total of 55,233 short tons, valued at $156,947. This was an increase of 18,868 short tons in production and of $12,738 in value. The quarries of Wisconsin and Virginia were idle in 1903, as were also several in other States. The States that furnished the production of 1803 were Connecticut, Maryland, New York, North Carolina and Pennsylvania.

These figures do not represent the entire amount of flint consumed annually in the United States, for much is imported from Europe in the form of rolled flints. The value of the flints and flint stone, unground, imported in 1903, was $101,103.

The production of feldspar in 1903 amounted to 13,432 short tons of crude eldspar, valued at $51,036, and 28,459 short tons of ground feldspar, valued at $205,697, a total of 41,891 short tons valued at $256,733. This is a decrease from the total production of 1901 of 3,396 short tons, but an increase in value of $6,311. The States that contributed to this production were Connecticut, Maine, Maryland, New York and Pennsylvania. These figures do not show the entire amount of spar consumed in this country annually, for some is imported from Canada.

The above data are taken from a report made to the United States Geological Survey by Dr. Heinrich Ries, on the production of flint and feldspar in 1903. The report is an extract from the forthcoming volume on "Mineral Resources of the United States in 1903," which may be obtained, free of charge, from the Director of the United States Geological Survey, Washington, D. C.

BORAX IN THE UNITED STATES.

The borax fields of the United States are mainly in the desert "dry lake" region of Southern California, though deposits are found also in Nevada and Oregon. Borax was first produced in the United States in 1864, at Borax Lake, California. The borax was contained in the water of the lake and was obtained by evaporation.

The saline crusts of the so-called dry lakes or borax marshes of the Mohave Valley were next mined for borax, and afterward, about in 1888, work was begun on the beds of colemanite, or borate of lime, in San Bernardino County, Cal., from which most of the borax mined in the United States has since been obtained.

The amount of crude borax produced in the United States in 1903 was 34,430 short tons, valued at $661,400. The production in 1902 was 17,404 short tons of refined borax, valued at $2,447,614, and 2,600 short tons of crude borax, valued at $91,000, a total of 20,004 short tons, valued at $2,538,614. Of the refined borax 862 short tons, valued at $150,000, were boric acid. Had the valuation in 1903 been taken on the refined instead of the crude product, the figures would have been $2,735,000 instead of $661,400.

The amount of borax, borates and boric acid imported into the United States in 1902 was 1,694,251 pounds, valued at $63,236. In 1903 the amount imported was 909,251 pounds, valued at $47,018.

Refineries for borax are located at Bayonne, N. J., Brooklyn, N. Y., New Brighton, Pa., Chicago, Ill., and San Francisco, Cal., where various more or less secret processes are employed to convert the crude material into products designed for various uses.

Borax is used for many purposes. When melted at a high temperature it dissolves metallic oxides and forms transparent colored glasses. It is used as a flux in welding metals and in melting gold and silver. It is employed in the manufacture of granite iron ware and of enameled bath tubs and other articles, as well as in making pottery and earthenware. Manufacturers of the hard, tough grades of glass and of encaustic tiles are large users of borax. It is used by painters, tanners, hat makers and calico makers, as well as by beef packers.

The domestic uses of borax are widely known, and in chemistry and metallurgy the borates are employed in many ways.

A clear account of the borax industry in the United States is given in a pamphlet entitled "The Production of Borax in 1903," by Charles G. Yale, forming a chapter in "Mineral Resources of the United States, 1903," from which the above facts have been taken. This pamphlet, which contains detailed statistics covering the production and importation of borax in 1902 and previous years, is printed for gratuitous distribution and may be had by application to the Director of the United States Geological Survey.

QUICKSILVER MINES IN PERU.

In a recent bulletin issued by the *Cuerpo del Ingenieros de Minas del Peru*, Augusto F. Umlauff gives an interesting account of the ancient quicksilver mines of Huancavelica. The mines were discovered in 1566, and during their long career have made an estimated output of 1,116,235 quintals (55,800 metric tons) of quicksilver. The last period of successful operation was from 1846 to 1849, when the production averaged 20 quintals per week. The ore is cinnabar and occurs in veins and stockworks intersecting a series of sedimentary rocks, mostly limestone, sandstone and quartzite, and as disseminated masses along the contact of igneous intrusions. Altogether the deposits can be traced from Chunamachay on the northwest to San Antonio on the southeast, a distance of several kilometers, although not in a continuous line. Samples taken by the writer from the old workings indicate that the ore runs about 2 per cent quicksilver. Beside the ore-bodies still remaining in the mines there are several heaps of waste and spent ore, aggregating 150,000 tons, which average 0·1 per cent. metal. The mines are situated 458 kilometers by wagon road from the port of Callao at an elevation of 14,000 feet above sea-level.—*Engineering and Mining Journal.*

LIFE HISTORY OF RADIUM.

The view that uranium is the parent substance of radium was advanced by Rutherford and Soddy on the ground that it is one of the few elements having a higher atomic weight, that it is the main constituent of radium ores, and that the proportion of radium in good pitchblende corresponds roughly with the ratio of activity of radium and uranium. An examination of a number of specimens of uranium salts purchased from seventeen to twenty-five

years ago showed that these all contained a larger proportion of radium than the more modern specimens. This result is in accordance with the theory enunciated by Rutherford and Soddy, but may easily be due to modified methods of preparation. F. Soddy (*Nature*, 70, p. 30, May 12, 1904), states that a kilogram of uranium nitrate was purified until the proportion of radium present was less than 10^{-13} gram as tested by the maximum amount of accumulated emanation. At the end of twelve months the amount of accumulated radium was certainly less than 10^{-11} gram instead of the 5×10^{-7} gram calculated from the ratio of the radio-activities of radium and uranium. The quantity of radium produced was therefore less than one ten-thousandth part of the theoretical quantity, and this result practically settles, in a negative sense, the question of the production of radium directly from uranium. It is, of course, possible that intermediate substances might exist, and that radium would only be produced at a later stage, but there is no experimental evidence in support of this view.

HENDERSON PROCESS OF COPPER EXTRACTION.

At wet copper works in Great Britain more difficulty is experienced than in alkali works generally, in keeping the chlorhydric acid gas evolved within due limits, partly because it has not proved convenient to construct the furnaces on the plus-pressure principle, as is usually the case. Dr. Affleck has reported ("Fortieth Alkali Works Report") that by burning a certain proportion of pyrites fines in a special furnace apart, at certain intervals, and mingling the gases with those from the other furnaces, in which the mixture of burnt copper ore with salt is calcined, all excess of chlorine in the gases is reduced, obviating the difficulty of absorption which otherwise arises.

THE RELATIVE EFFICIENCY OF THE STEAM TURBINE AND THE RECIPROCATING ENGINE.

The question of the relative efficiency of the steam turbine and the reciprocating engine is widely debated, and yet unsettled. In general the turbine seems to have the better of the argument for large units for steady duty, where superheated steam is used and a low vacuum maintained for the exhaust. The question of the efficiency of the high duty turbine or centrifugal pump is more debatable, though such pumps are in successful service at mines in continental Europe, and several concerns are manufacturing them in this country and giving out statements as to the work the pumps will do. It would seem from the present status of the arguments that the chief factor that manufacturers will have to overcome in centrifugal pumps for high lifts will be that of deterioration from use, particularly where mine waters are acid or gritty. A worn valve in a direct-acting pump, of good construction, can be replaced cheaply. Any wear of propeller blades, however, is likely to lead to considerable slip losses when working against high heads, and replacements seem likely to be costly. However, the theoretical advantages of the centrifugal pump, its compactness and possible high efficiency, will undoubtedly lead to its being given extended tests under conditions that will bring out any defects.—*Engineering and Mining Journal.*

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, October 19, 1904.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 19, 1904.

MR. H. R. HEYL in the chair.

Present, 60 members and visitors.

Additions to membership since last report, 8.

The chairman introduced Mr. J. Wilmer Henszey, of the Baldwin Locomotive Works, who delivered an interesting address "On the Organization and Methods of a Great Modern Industrial Works," using the Baldwin establishment as a typical example. Mr. Henszey's remarks were illustrated by the exhibition of a large number of lantern photographs of the various departments and shops. The paper will appear in the JOURNAL.

Mr. W. N. Jennings exhibited and commented on a large series of lantern photographs representing views taken in the course of a recent trip through the Yellowstone Park and the Canadian Rockies.

The communications of the evening were well received, and the chairman expressed the thanks of the meeting to the contributors.

Adjourned. WM. H. WAHL,
Secretary.

Committee on Science and the Arts.

(*Abstract of proceedings of the stated meeting held Wednesday, October 5, 1904.*)

MR. LOUIS E. LEVY in the chair.

The following reports were adopted:

(No. 2301.) *Hydraulically-forged Steel Car Wheel.* H. V. Loss, Philadelphia.

ABSTRACT: The report gives a historical sketch of the development of the inventions of Mr. Loss for producing a finished wheel of steel. For details of the machinery and methods designed by the inventor, the reader is invited to refer to the JOURNAL for May, 1904.

It appears that several mills have been built in Germany for rolling the centers of the wheels, the tires being produced in the ordinary tire mill and attached by various methods to these rolled centers. The Loss improvements, which had as their starting point the German practice, advanced the art to the rolling of the flange as well as the wheel center. The report then proceeds to describe the hydraulic press which the applicant devised for this purpose (U. S. Patent, No. 710,286, September 30, 1902), and which constitutes an excellent piece of mechanical design, and embraces several novel and original features; as, for example, the operation of the independent hydraulic ram, respectively for forging and punching, and which can be used in conjunction for exerting intense moulding pressure on the work.

The report further commends the ingenious method of releasing and withdrawing the punch; the method of discharging the punchings, and

also of taking the compressed blank out of the die. These features are referred to as examples of good mechanical design.

Referring to the illustrations accompanying Mr. Loss's papers (J.F.I., May, 1904), showing the machine in the Schoen works, near Pittsburg. the report states that while this is similar in general design to the original German mill, Mr. Loss has added some features which permit of the rolling of the flange of the wheel, making a much more powerful mill and applying much greater motive power than originally contemplated.

An adjustable external roll was applied for this purpose, together with companion rolls for finishing the flange, and side rolls for finishing the edge of flange, for detailed description of which reference is made to U. S. Patent, No. 706,674, August 12, 1902.

This machine has been in use in the Pittsburg works for the past year, and a considerable number of wheels have been successfully made and placed in service.

The report concludes as follows :

"The value of the process from a commercial point of view can only be told by experience, but the successful working of the machine and the convenience with which it can be operated bear testimony to the mechanical skill displayed by Mr. Loss in the execution of the designs. As there are doubts about any substantial originality in the design of the rolling mill, the Committee prefers to give precedence to the subject of the hydraulic press ; and, in consideration of its many novel features so well adapted for the intended purpose and the mechanical skill displayed, it is believed that he has accomplished a desirable advancement in the method of producing solid, rolled steel, car wheels. . . . The wheel blanks, instead of being cast to form, are now cast from slabs, rolled from the ordinary ingot, a method which should insure greater solidity and homogeneity than if cast to shape."

In view of the foregoing facts, the award of the John Scott Legacy Premium and Medal is recommended to Mr. H. V. Loss, for his improvement in the production of solid rolled steel car wheels. (*Sub-Committee*, James Christie, chairman ; Chas. Day, Robert Job.)

(No. 2332.) *Ratchet Tools.* North Bros., Philadelphia.

ABSTRACT: The object of this invention is to provide a compact, simple, powerful, reversible, and at the same time cheaply-made, ratchet.

This has been accomplished by abandoning entirely the conventional pawl carried by a pivot and vibrating in the plane of the toothed wheel, and substituting a thrust-block, which bears against the tooth of the wheel on one side and the casing on the other, thus giving a maximum of strength and simplicity in a minimum of space. The strength, instead of being limited by that of the pivot of a pawl, as in the usual case, is only limited by the size of the tooth in the wheel. The thrust-block is subjected only to compression, and can be made stronger than the tooth and at the same time be kept small in size and space occupied.

The simple and effective methods by which these thrust-blocks are made to transmit motion from the casing to the toothed wheel in either or both directions are fully described and illustrated by U. S. letters-patent Nos. 537,681, April 15, 1895, and 593,157, November 2, 1897, to which reference is made.

A very strong and efficient chuck is also provided at the end of the spindles of the tools for holding the bits.

The ingenious and effective manner in which this ratchet and chuck have been applied to hand tools for operating screw drivers and drills can best be appreciated by an examination and trial.

On account of the compactness, simplicity, strength and convenience of the tools, combined with the superior workmanship and economical production, due to efficient method and system of manufacture, the award of the John Scott Legacy Premium and Medal is recommended to be given to Zachary T. Furbish for his ratchet tools. (*Sub-Committee*, Wm. H. Thorne, chairman; D. Eppelsheimer, Jr., Arthur Falkenau.)

(No. 2334.) *Counterbore.* Robert E. Duvall, Philadelphia.

An advisory report.

The following reports passed first reading:

(No. 2284.) *Wire-testing Machine.* Falkenau & Sinclair, Philadelphia.

(No. 2340.) *Flanging and Expanding Machinery.* Luther D. Lovekin, Camden, N. J.

Sections.

[*Abstracts of stated meetings.*]

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Thursday, October 6th, 8 P.M. Dr. Wahl in the chair. Present, 71 members and visitors.

Prof. A. E. Outerbridge made the inaugural address of the season on the subject of "The Molecule, the Atom and the Present Theory of Matter." The paper was discussed freely by Dr. E. Goldsmith, Mr. Waldemar Lee, the chairman and the author. It has been requested for publication.

The chairman *pro tem.* extended the thanks of the Section to Professor Outerbridge, and adjourned the meeting.

WM. H. WAHL,
Secretary pro tem.

CHEMICAL SECTION.—*Stated Meeting*, held Thursday, October 13th, 8 P.M.

Dr. W. J. Williams in the chair. Present, 27 members and visitors.

The chairman introduced Mr. Waldemar Lee, who addressed the Section on "The Contact Process for Sulphuric Acid." Discussed by Dr. E. Goldsmith, Geo. P. Scholl and the author.

Dr. Bruno Terns followed with a paper on some problems in industrial chemistry. Following are the principal subjects discussed by the speaker, viz.:

"The Progress of the Coke-Oven By-Product Industry in the United States since 1891."

"The Manufacture of High-Grade Ammoniated Phosphates by the Direct Use of the Crude Ammoniacal Liquors of the Coke-Oven Industry."

"The Coke-Oven Process Applied to the Utilization of Garbage."

"Other Sources of Ammonia for the Fertilizer Industry."

Both papers are reserved for publication.

Adjourned.

WM. H. WAHL,
Secretary pro tem.

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THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, October 19, 1904.

The Organization and Methods of a Modern Industrial Works.

BY J. WILMER HENSZEY.

The Baldwin Locomotive Works, in Philadelphia, is probably as good an example of a modern industrial works as we have in the country, and as I have been connected with this company for some years I will endeavor to give you an idea of how that plant is operated.

Baldwin Locomotive Works, at the present time, employ about 15,500 men, who are divided among twenty departments. The executive force consists of one superintendent, four assistant superintendents and twenty foremen. Owing to the extent of the works it is divided into two divisions, the eastern embracing all shops east of Fifteenth Street, and the western division taking in all shops west of Fifteenth Street, also new shops located at Twenty-sixth, Twenty-seventh and Twenty-eighth Streets. Each division

is in charge of an assistant superintendent, who works in conjunction with the foreman in his division.

In the eastern division the most important shop is the Erecting or Finishing Shop, located at Broad and Spring Garden Streets. This shop employs about 2,500 men, and has a capacity of fifty finished locomotives every week. To operate this department we have one foreman, two assistant foremen and twenty track foremen. Every track foreman is a specialist on a certain line, such as erecting, valve-setting, testing, etc., and has direct charge of the gang bosses and men who work under his supervision. The gang bosses, or contractors as we call them, are all picked men, the very best we can find, and have direct charge of the workmen. This same system of contracts is employed in every department throughout the works.

I will now explain our contract or piece-work system. Every department is a factory, manufacturing a certain number of locomotive parts. Through careful study we are able to ascertain the exact time and expense involved in making these parts; we then allow a certain amount of profit for the contractor in making price; he, in turn, gives out his work—piece-work—to his men at a slightly lower rate and makes the difference. There is a great diversity of opinion among manufacturers about the best way to pay labor. Some claim that you do not get the best results from the piece-work system because a piece-worker knows that he will not be allowed to make over a certain amount, and if he finds that he is making too much he will curtail his output sooner than run the chance of having his prices cut. This is true in some cases, but, under careful management, on routine work cannot occur. We expect and get more work per man out of our piece-workers than any similar concern in the world, and our men are allowed to make higher wages, and this, to my mind, explains why we never have strikes at Baldwin's.

In hiring a man we never ask whether he belongs to a union or not. We don't care. If he enters our employ he abides by our rules and regulations, which are posted in every department, and any attempt to incite trouble or dis-

satisfaction among the men is reported at once by his contractor and the man is dismissed.

A question that is often asked is, "Do you not have great trouble in procuring workmen who are skilled in the special lines of locomotive works?" We do. This is the question to which the Baldwin firm has given a great deal of attention in the past four years, and has led to the revival in our works of the old apprenticeship system, a brief outline of which may be interesting.

The apprentices are divided into three classes, first, second and third. To be a first-class apprentice a boy must be 17 years old and must have at least a grammar-school education. He serves four years. During this time he is allowed to stay on one class of work only three months, and is moved from department to department until he covers the entire plant. During the school season he is obliged to attend night-school two nights a week, taking up a special course in higher mathematics and mechanical drawing. He is paid from $3.00 to $6.60 per week during apprenticeship, and on completion of time receives a certificate and $250. A second-class apprentice must be a high-school graduate and serve three years on same lines as first-class apprentice. He also attends night-school. He gets from $4.20 to $6.60 per week, and on completion of time receives a certificate and $200. A third-class apprentice must be a graduate of a recognized technical school. He serves two years and does not take a night course. He gets from $9.00 to $12.00 per week and receives a certificate on completion of time.

We now have between 400 and 500 apprentices of the several classes, and it is proving of vast benefit to the works in providing a more intelligent and better class of labor than it is possible to get in any other way.

We claim that whether the apprentice stays with us or not on the completion of his time, he will always be a friend to the Baldwin Locomotive Works and look out for our interests, just as a college man does for his college. His training has made him a valuable man for railroad work, and one who will get ahead. It is a far-sighted business proposition.

A manager of a large shop has many other important matters to look after. If he is a progressive man, backed by a progressive firm, he wants to know the quickest and best way to get out work. Our firm encourages this among the foremen, and sends them all over the country to see how other people do work. If a foreman can prove that by the use of certain tools and appliances he can save time and expense, they are furnished him without question. During the past five years enormous strides have been made in this direction. By the aid of improved hydraulic and pneumatic tools hand-work has been reduced to a minimum, and on this alone nearly $1,000,000 a year is being saved on the cost of work in the shops. We have also made great savings on time required to do work by the use of specially treated tool steel for machine tools. By means of these tools we have been able to increase the capacity of some of our machines from 30 per cent. to 50 per cent. Our best results have been obtained from the Burgess Special Steel and the Sanderson Special Steel. All our new tools are being made from these steels, as ordinary tool steel will not stand the high speeds at which our tools are now being run.

It is interesting to see the vast difference between an up-to-date railroad or locomotive shop in this country and a similar shop on the other side. It has been my opportunity to visit a number of these shops in England, Sweden, Finland and Russia, and it is surprising to note the condition of their equipment. Power cranes are very rare even in the larger shops and the machinery is of a type in use here twenty-five or thirty years ago. It is not strange, noting these conditions, that we can build locomotives in Philadelphia, ship them to any country in Europe, and put them in service on their railroads, 10 to 20 per cent. cheaper than they can build in their own shops.

As orders for locomotives are received, they are printed on lists and put out in the shops. Each list contains two weeks' work; they are dated with delivery dates for each class of work in the various departments.

"The designation of the different classes of locomotives as used by Baldwin Locomotive Works embodies the com-

bination of certain figures with one of the letters *A*, *B*, *C*, *D*, *E* and *F*, to indicate both the number and kind of wheels and the size of cylinders. Thus, a locomotive having one pair of drivers is classed *B;* that with two pairs, *C;* that with three pairs, *D;* that with four pairs, *E*, and that with five pairs, *F*. The letter *A* is used for a special class of high-speed locomotive with a single pair of drivers. A figure 4, 6, 8, 10, 12 and 14 is used as an initial figure to indicate the total number of wheels under a locomotive. A figure or figures following the initial figure indicates diameter of cylinders, and the figure or figures following a class designation represents the consecutive class number of a locomotive on which it appears. Thus, 8 26 *C* 500 indicates a locomotive with eight wheels in all, having cylinders 16 inches in diameter with two pairs of driving wheels, and the 500 locomotive of its class." As soon as lists are put out, the Drawing-Rooms get them and start at once to design the locomotive, furnishing bills of material to the Purchasing Department, which orders all material we do not make. Lists are also furnished to every foreman and contractor in the entire plant. The great advantage of these lists is that every man in the entire works is after the material he needs long before it is wanted in the Erecting Shop, and we are rarely subjected to delay on delivery dates. Every foreman has a book of lists—check-books we call them—in which he keeps an exact daily check of every piece of work made in his department. He, in turn, checks off the superintendents', who can tell by their books at a glance the exact condition of every locomotive part in the entire works.

An important factor in the management of a large plant is the system of accounts.

"The Baldwin Locomotive Works keep two sets of accounts, viz.:

"(1) Manufacturing Account.

"(2) Commercial or Financial Accounts.

"In the manufacturing books a ledger account is kept with each locomotive constructed and with each repair-work job. All materials and labor are charged to these accounts either directly or eventually on closing the books. The

principle is that no material or labor is paid for without being charged to an appropriate account.

"In the commercial books accounts of dealings with individuals and corporations are kept in the ordinary way. Both sets of books are closed annually and correspond exactly in their statements of expenditures and receipts.

"System of manufacturing accounts:

"In the general system of accounts by which the cost of construction of locomotives is ascertained each locomotive is charged as follows:

"A—*Materials.*—All materials used in the construction of the locomotives at the actual cost as fixed in the general contracts covering such purchases, or as paid for same at market rates.

"B—*Distributed Labor.*—All labor charged directly to the locomotives at actual cost of same, either by piece-work or day-work rate.

"C—*Expenses.*—All labor and materials incident to the construction of the locomotives, but which from their character cannot be charged direct. The cost of these is distributed to the locomotives in the proportion fixed by the amount of distributed labor as per paragraph B. Until this proportion is finally determined for each year it is based upon the accounts for the preceding year. The expenses include wages of managers, foremen, clerks, draughtsmen, stationary engineers, teamsters, laborers, watchmen, traveling engineers and messengers. They also include heating, lighting, repairs, insurance, taxes and other expenses on buildings, and tools, patterns and dies, defective work, printing, advertising, traveling expenses and all incidental costs connected with manufacture.

"D—*Disbursements for Freight and Delivering Locomotives.*—These consist of railroad charges for transportation to point of delivery."

The aggregate of the foregoing items is the cost of manufacture and delivery of locomotives.

One of the most important departments and one whose influence is felt over the entire works is the Test Department. This is equipped with two Tinius Olsen testing

machines for physical tests, and a complete chemical laboratory for chemical analyses, also with apparatus for indicating locomotives and stationary engines. Nearly all the material we use must first pass through this department, and be reported on before being accepted; this applies to all boiler steel, spring steel, tank steel, bar iron, cylinder iron, steel castings, oils, paints, etc. We have fixed standards for all these materials, which must be complied with before materials are accepted. The Test Department also has a corps of inspectors, who are stationed in the various rolling-mills and steel-plants we deal with, and whose duty it is to see that our mill specifications are lived up to, and that our orders are rushed through.

One of the important duties of a shop manager is the care of machinery. These machines represent thousands of dollars, and it is of the utmost importance that they be kept in perfect repair. To accomplish this we have in every shop a machine inspector or tool boss. This man is an expert on repair work, and has a gang of machinists under his supervision. As soon as a machine breaks, the fact is reported to the tool boss, who repairs it at once. A number of duplicate pieces of the most breakable parts of machines are always kept in stock, so that the machines are seldom down but for a very short time.

In every large plant, especially one having large smith shops and foundries, there is a constant danger of fire; to overcome this we have, I think, one of the largest volunteer fire departments in the country, having about 200 picked men scattered all over the works. We have twelve large Barr pumps and as complete apparatus as the city department. Every shop also is equipped with a sprinkler system, and has stand-pipes and reels of hose on every floor. Every few weeks we have fire drills, and it is remarkable how quickly our men can get into service. They put out on an average of two or three fires a month, and for several years have not had to call on the City Fire Department.

Another important matter is shop cleanliness. The sweepings must be run through separators, then loaded on cars and sent to firms who buy all our turnings.

Our sheet-iron scrap is carted to large scrap-bins built over railroad tracks in one of our yards. These bins have hinged bottoms, and when they are full, cars are run under them and loaded. This material is also sold, and proceeds from scrap and turnings amount to several hundred dollars a week.

The power of the works is handled by the Highway Department, which is also responsible for buildings, electric power and light and machinery repairs. We have four large power-houses, one at Broad Street, one at Sixteenth Street, one at Seventeenth Street, and one at Twenty-seventh Street, having thirty-one boilers generating 10,684 horse-power. Each power-house is in charge of a chief engineer, who makes a daily report to Highway office on a special form, giving an hourly account of steam and air pressures, and of the boilers, engines and compressors that were in service. By this means the foreman of the Highway Department is kept in contact with the power service throughout the entire works, and knows exactly how the pressures are being maintained at every hour of the day. We have 108 engines, pumps and air compressors, with 8,656 horse-power. All air compressors, dynamos for light and power and engines running them are located in power-houses, the other engines being located in the various shops.

As I have already stated, we employ 15,500 men, and to keep account of their time and wages is the work of our Time Department. Each man, on being hired, is given a number. The numbers for the men in each shop run in rotation. Each contractor has a piece-work book, in which he keeps a daily account of the time and wages made by each man in his gang. The time of all day workers is kept in a day-work time-book by the time-clerk. Once a week the Time Department takes the time records from the piece- and day-work books, entering the same on long printed sheets, giving the name and number of every man in each department. The piece-work books are gone over, and charges against each locomotive are entered to its cost account. The account of the wages due each man is then turned over to the Pay Department.

The Pay Department has pay envelopes stamped with the name and number of every man in the entire works. The amount of wages due is now stamped on each envelope. Our regular pay-day, with the exception of holidays, is on Friday, and every Friday morning the money is brought from bank. It has always been our custom to pay in coin, which is easier to handle, and clerks are less liable to make mistakes. The amount stamped on each envelope is then put in, the envelope is sealed and all are arranged in rotation, as to number, in an upright position, in specially constructed racks, each rack holding about 200 envelopes. These racks when filled are put in safes built for this purpose, and are now ready for the paymasters. We have two pay stations—one at Broad Street, in the Erecting Shop, and another at Seventeenth and Hamilton Streets. At the signal to quit work on Friday night, the men arrange themselves in long lines, according to number, at their respective pay stations, and at five minutes after 6 the line starts. We have eight paymasters, and run eight lines, the foreman of each shop, and his assistants, having charge of the lines his men are in. Each man as he passes the pay desk calls out his number to his foreman and his name to the paymaster, who passes him his envelope. It is possible in this way to pay our entire force in thirty minutes.

In conclusion, I will say that, to my mind, to get the best results from a shop you must have a unity of feeling among your men. Every man should be treated as a man, not as a machine. If a man comes to tell you about a supposed or a real wrong, he should be listened to, and given the proper advice. Your superintendents and foremen should not be shut up in offices to which the ordinary workman cannot have access, but should be as get-at-able as possible. This is, and has been, the policy of the Baldwin Locomotive Works, and to this policy their success, I believe, may, in large measure, be attributed.

THE STRENGTH OF STEEL AT HIGH TEMPERATURES.

Prof. C. Bach has presented in the *Zeitschrift des Vereines Deutscher Ingenieure* the results of an elaborate series of tests of the strength of steel at high temperatures. Bars from three different works were tested, these being distinguished by the letters *O*, *K* and *M*. Of the bars *O*, four were subjected to tensile tests at ordinary temperatures, and successive lots of four to tests at the temperatures 200, 300, 400, 500 and 550° C. At ordinary temperatures the strength of the steel was for bar No. 2, for example, 27 tons per square inch, the ultimate extension on a gauge length of 8 inches 26·3 per cent. and contraction of area 46·9 per cent. The results of the tests showed that the strength increased up to 300° C. by about 3·17 tons per square inch, and from this temperature onward the strength fell, roughly in proportion to the temperature, to 13·1 tons per square inch at 550° C. The ultimate extension decreased from 25·5 per cent. at ordinary temperatures to 7·7 per cent. at 200° C., from which again it rose to 39·5 per cent. at 550° C. The contraction of area also fell at 200° C., but did not commence to rise until the temperature was above 300° C. In the case of the bars from the works distinguished by the letters *K* and *M*, tests were made by keeping the loads on for a considerable time. This prolonging of the action of the load had no effect until the temperature reached 300° C., at which point it caused a slight decrease of strength, and at 400 and 500 degrees a greater decrease. As regards the effect of prolonged loading on the extension and contraction between the temperatures of 300 and 400° C. it caused an increase in both, but from 400° C. the extension and contraction under prolonged loading decreased until at 500° C. they were lower by from 20 to 25 per cent. than with ordinary duration of test.

Professor Bach draws the conclusion from his investigations that for steam boilers, piping, etc., the strength of steel should be tested at the higher temperatures; and he is of opinion that this conclusion is justified not only by his experiments, but from the well-known fact of the brittleness of steel when worked at a blue heat.

DAMMING THE THAMES.

The damming of the River Thames at London is being considered by a royal commission. As there is a difference between high and low tide of 18 or 20 feet, all larger vessels must be handled in docks which can be closed by tidal gates. The object of the commission is to devise means for doing away with this inconvenience, and thus increasing the shipping facilities of the port. Among the plans presented is one for constructing a great dam across the Thames from Gravesend to Tilbury. This would convert the river into a great inland lake, extending from Gravesend to Richmond. At the point selected for the dam the river bed is of fine chalk, and the structure would give a navigable depth of 65 feet at Gravesend and 13 feet at London Bridge, without any dredging. The proposed dam would be made of concrete, granite-faced. The four locks would be 300, 500, 700 and 1,000 feet long and from 80 to 100 feet wide. The estimated cost is $18,290,000. As all the docks could be left open, there would be an annual saving of $250,000 in the cost of operating the gates.—*Iron Age.*

Mining and Metallurgical Section.

Stated Meeting, held Thursday, October 6, 1904.

The Molecule, the Atom and the New Theory of Matter.

BY A. E. OUTERBRIDGE, JR.,
Professor of Metallurgy, Franklin Institute.

[At the Franklin Institute, on Thursday evening, October 6th, Prof. A. E. Outerbridge, Jr., opened the proceedings of the sections by a highly interesting paper on the "New Theory of Matter," of which the following is an abstract.—ED.]

The speaker said that twenty years ago he had given an address on "Radiant Matter" in the Auditorium at the Electrical Exhibition of the Franklin Institute, and since that time amazing discoveries have been made in cognate branches of science, causing new conceptions of the nature of the ultimate particles of matter out of which worlds are formed to dawn upon the minds of leaders of thought.

When philosophers like Lord Kelvin, Sir William Ramsey, Sir Oliver Lodge, Sir William Crookes and others, admit that the discovery of radium has upset all our preconceived ideas of the nature of matter, it behooves us to re-examine carefully the ground upon which we stand and try to comprehend the new views that have been advanced by such leaders.

The delicacy of the apparatus devised by modern physicists, and the refinement of experimental research rendered possible thereby, are among the greatest marvels of this wonderful age. The physicist is pushing his researches into paths which but a few years ago were thought to be forever hidden somewhere in the vast realm of the unknowable, and the boundary line between so-called physical and metaphysical science is continually narrowing; the philosopher has advanced, step by step, until he seems almost to have grasped the ultimate particles which constitute the physical

basis of the universe, and to have revealed to mortal eyes particles of matter too minute even for the mind's eye to comprehend.

It is a significant observation that all modern research tends to simplify Nature's laws, to show their intimate correlation and even to point still farther toward a complete unification or oneness of origin; thus the great forces of light, heat and electricity, though differing so widely in their effects on our senses, have all been resolved into "modes of motion," and it would seem a natural inference from the trend of modern scientific speculation that the now seemingly complex laws of nature's forces may all come at some future day—not far distant perhaps—to be comprehended in the study of the laws of motion.

Even matter itself, in its final analysis, is thought by some philosophers to owe its protean forms solely to difference in the movement of molecules or atoms; some years ago Lord Kelvin said: "That which we call matter may be only the rotating portions of something which fills the whole of space, *i. e.*, vortex motion of an everywhere-present fluid."

Professor Tait, following along the same path, said: "This property of rotation may be the basis of all that appeals to our senses as matter."

Professor Crookes said: "From this point of view, then, matter is but a mode of motion."

These views, which startled us when first announced, have been the advance couriers preparing us for the still more surprising statements recently put forth by leaders of scientific thought regarding the nature of matter.

The speaker said that before asking attention to the latest views regarding the nature of the ultimate particles of matter, it might be well to review very briefly some of the well-known laws and generally accepted theories regarding molecules and atoms.

The wonderful divisibility of matter has attracted attention from early times, and it was long thought that no absolute knowledge could ever be obtained regarding the nature of the infinitesimal particles out of which worlds

are formed. Indeed, one scientist, eminent in his day, said: "Of the ultimate nature of matter the human faculties cannot take cognizance, nor can data be furnished by observation or experiment on which to found an investigation of it." Lord Kelvin said, more recently, that they are "pieces of matter of measurable dimensions, with shape, motion and laws of action; intelligible subjects of scientific investigation." The same authority, undaunted by the complexity of the problems, deduced approximately, by four separate and distinct methods of calculation, the ultimate size of molecules, and in order to make the minute dimensions more readily comprehensible he has given this illustration: "Imagine a drop of rain, or a glass sphere the size of a pea, magnified to the size of the earth, the molecules in it being increased in the same proportion, the structure of the mass would then be coarser than that of a heap of fine shot, but probably not so coarse as that of a heap of cricket-balls." This represents the "coarse-grainedness" of matter.

Tyndall, in his charming "Fragments of Science," has given us some interesting ideas regarding the size of the particles constituting cometary matter. He says: "From their perviousness to stellar light and other considerations Sir John Herschel drew some startling conclusions regarding the density and weight of comets. These extraordinary and mysterious bodies sometimes throw out tails 100,000,000 miles in length and 50,000 miles in diameter. Now, suppose the whole of this stuff (*i. e.*, the matter forming the tail) to be swept together and suitably compressed, what do you suppose its volume would be? Sir John Herschel would probably tell you that the whole mass might be carted away, at a single effort, by one of your dray-horses. In fact, I do not know that he would require more than a small fraction of a horse-power to remove the cometary dust.

"After this you will hardly regard as monstrous a notion I have sometimes entertained, concerning the quantity of matter in our sky. Suppose a shell to surround the earth at a distance which would place it beyond the grosser matter that hangs in the lower regions of the air, say at the

height of the Matterhorn or Mont Blanc. Outside this shell we have the deep blue firmament. Let the atmospheric space beyond the shell be swept clean and the sky-matter properly gathered up. What would be its probable amount? I have sometimes thought that a lady's portmanteau would contain it all. I have thought that even a gentleman's portmanteau, possibly his snuff-box, might take it in. Whether the actual sky be capable of this amount of condensation or not, I entertain no doubt that a sky quite as vast as ours, and as good in appearance, can be formed from a quantity of matter which might be held in the hollow of the hand."

The divisibility of matter is at once a physical and a metaphysical question. It is obvious that masses of every form of matter known—saving perhaps the light-ether—are capable of division with more or less readiness. But is there any limit to this division other than the imperfection of the means employed? Here physics and metaphysics are at variance, and the former boldly avers that there is a limit. "A fragment of salt, for example, sustains subdivision only to a certain extent. Divide it but once again, and the salt as such disappears, and in its place we have the two new substances, sodium and chlorine. This limiting particle is called a molecule. It is the smallest particle of any substance which can exhibit the chemical properties of that substance. The aggregation of molecules constitutes a mass; hence the molecule is the physical unit—the ultimate particle or center of the physical forces. . . . An atom is the smallest portion of matter which can be reached by nature's processes of subdivision. It is generally defined as the smallest particle of simple matter which can enter into the composition of a molecule. . . . The word atom came into use to express a universally conceded fact expressed in the law of definite proportions, namely, that a certain definite quantity of matter by weight combines with a similar definite quantity of some other matter. The smallest quantity of any substance which is found ever to enter into combination is called an atom. No real objection can lie against the idea of atom when defined in this

way. If we concede that the molecule has as real an existence as a mass, I see no reason for not conceding the same to the atom." *

The speaker referred to Sir Wm. Crookes' discoveries in "Radiant Matter," and read the following excerpt from a report printed in the *Journal of the Franklin Institute*, April, 1881, of an address which he had given at the Institute on Professor Crookes' "Fourth State of Matter."

We are now prepared to ask, what is the character of the ultimate particle? This is a problem which has exercised the philosophic mind for many generations. The celebrated Italian poet and philosopher, Lucretius, speculated on this topic, and left a work called "De Rerum Natura"—*of the nature of things*—embodying his views, which are interesting even at this day.

Sir Isaac Newton invented, or adopted, the theory that all matter was composed of little, hard, incompressible spheres. This theory afforded him a plausible and ingenious explanation of certain discrepancies which he found to exist between the real velocity of sound in air, as proved by experiment, compared with the theoretical velocity, as calculated by him, based upon seemingly correct data. The theory, however, was found to be untenable, and was long since overthrown.

The idea of motion, as associated intimately with matter in some vague and unexplained way, seemed to be intuitively felt to be a necessity even before the time of Faraday, and a reaction from the hard atom theory of Newton brought out a class of philosophers who maintained that the so-called atom was not material at all, but that there existed in space certain foci, or centers of force; these points were supposed to possess the properties of attraction, repulsion, etc., and to behave in other respects as the most approved atom. This idea is believed to have been at least countenanced, if not actually adopted, by Faraday.

The wonderful investigations of Helmholtz on rotary

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* "The Molecule and the Atom." G. F. Barker, *American Chemist*, November, 1876.

fluid motion paved the way for Sir Wm. Thomson's "Vortex Atom Theory."

This theory seems to explain many obscure phenomena, and, while we may hardly say that it is to-day the fully accepted creed of the scientific world, it is founded, not upon a rock, but upon the potent influence of the talismanic word motion, to whose eddying current the causes of so many of nature's grandest phenomena are now relegated.

"Sir Wm. Thomson's supposition is that the universe is filled with something which we have no right to call ordinary matter, but which we may call a perfect fluid; then, if any portions of it have vortex motion, they cannot part with it; it will remain with them forever, or at least until the creative act which produced it shall take it away again."*

This theory is far too complicated to admit of a clear exposition in a few words; but we will try to form an idea of it by means of a simple illustration. You know that a smoker may, by a peculiar adjustment of the mouth, accompanied by sudden muscular movements of the cheeks, skilfully exhale portions of the tobacco smoke in the form of beautiful opaque rings, which continue to rotate about their axes, gradually disappearing as the motion ceases; this is a vortex movement of the simplest order, and while it lasts the portions of the smoke forming the rings are separated and distinct from all the rest of the smoke in the room; and should this motion never cease (by the retarding influence of friction and gravitation), this smoke would remain differentiated forever and imbued with new properties in virtue of that vortex motion.

This crude illustration conveys the simplest idea of a most abstruse scientific speculation when referred to the hypothetical, all-pervading, perfect fluid, so essential to the existence of Sir Wm. Thomson's vortex atom.†

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* "Recent Advances in Science," P. G. Tait.

† The subject of rotary fluid motion is such a forbidding one, from a purely mathematical point of view, that no one had done more than take a look at it, as it were, until Helmholtz gave us the fundamental propositions; splendid as they are, they are only a first step. Indeed, to investigate what takes place when one circular vortex atom impinges upon another, and the whole

The speaker alluded to the theory of "Compressible Atoms" advanced by Prof. Theodore W. Richards, of Harvard University, and to the interesting relation thereto, as noticed by him, of the remarkable permanent expansion of cast iron (exceeding 40 per cent. in cubic volume) when subjected to repeated heating and cooling.* In a recent letter Professor Richards said: "The theory of compressible atoms bears upon all the points which you bring up, and it seems to me that all are explicable according to it. Let us suppose that in a given pure metal the atom is equally attracted on all sides, and therefore equally compressed on all sides (this may or may not be true, but will serve as an initial assumption). If now the material is fused with another, forming an alloy, the atoms of each, being no longer symmetrically surrounded, will be unsymmetrically compressed and the volume change would be a very complicated function. This would also be true even if, in the first place, the pure metal's atom were not symmetrically compressed; in this case the change would still be bound to occur when the environment is changed. These considerations apply to most of your observations I think. In the case of 'Invar'† we must imagine that some shifting of affinities as the temperature rises must cause a contracting effect, which counterbalances the normal expansion of heated substance. The case may be supposed to be analogous to the probable state of water about 4° C., or to your interesting shift of affinities on heating cast iron, except that in this last case the shift involves an expansion instead of a contraction. As I understand it, in your case

motion is not symmetrical about an axis, is a task which may employ perhaps the lifetimes for the next two or three generations of the best mathematicians in Europe, unless in the meantime some mathematical method, immensely more powerful than anything we at present have, should be devised for the special purpose of solving this problem.—P. G. Tait, "Recent Advances," p. 298.

* See "The Mobility of Molecules of Cast Iron." A. E. Outerbridge, Jr., *Transactions* American Institute of Mining Engineers, 1904, and *Journal of the Franklin Institute*, February, 1904.

† Invar is a new alloy of iron and nickel which expands almost inappreciably when heated to a high temperature.

the shift of affinity is made manifest by actual change of structure. In the case of 'Invar' it cannot go so far as this, at least with moderate temperatures; on cooling, the structure must settle back to what it was before cooling."

The speaker said that since the discovery of radium and its remarkable properties it has been generally admitted that our preconceived ideas regarding the indivisibility of the atom, and, indeed, the whole nature of atoms and molecules, or, in other words, the nature of matter itself, need modification; at the present moment the scientific world is in suspense regarding the future; it is a moment of uncertainty, and while we may properly feel great desire to comprehend the new ideas in the minds of leaders of thought, we will certainly be justified in exercising caution in accepting new and revolutionary theories until further light shall have been cast upon the whole subject; meanwhile it is fortunate, in view of the present uncertainty regarding the nature of the ultimate particles of matter, that it is quite immaterial to our physical welfare whether the atom be divisible or indivisible; compressible or incompressible; whether it be a solid sphere, as Newton thought, or a mere focus of force, as other philosophers have maintained; this is an abstruse subject of academical importance only.

In his address on "Radiant Matter," already alluded to, the speaker said: "That mysterious agency or force, called electricity, has been utilized not only for hundreds of practical purposes, so fully illustrated in this grand electrical exhibition, but it has been employed by the physicist as a sort of finger to probe Nature's inmost structure, and it has enabled him not only, as it were, to see her mind, but, in some sense, to feel her pulse." Now we are actually told that electricity is the basis of all matter. This is the new theory.

Sir Oliver Lodge, F.R.S., in a recent paper entitled "Electric Theory of Matter," says: "What electricity itself is we do not know, but it may perhaps be a form or aspect of matter; so have taught for thirty years the disciples of Clerk-Maxwell. Now we can go one step further and say. matter is composed of electricity, and of nothing else—a thesis which I wish to explain and partially justify. * * *

"Our present view of an atom of matter is something like the following: Picture to one's self an individualized mass of positive electricity diffused uniformly over a space as big as an atom—say a sphere of which two hundred million could lie edge to edge in an inch, or such that a million million million million could be crowded tightly together in an apothecary's grain. Then imagine, disseminated throughout this small spherical region, a number of minute specks of negative electricity, all exactly alike, and all flying about vigorously, each of them repelling every other, but all attracted and kept in their orbits by the mass of positive electricity in which they are imbedded and flying about.* *

"Different atoms, that is, atoms of different kinds of matter, are all believed to be composed in the same way; but if the atoms of a substance are such that each possesses twenty-three times as many electrons as hydrogen has, we call it sodium. If each atom has 200 times as many as hydrogen, we call it lead or quicksilver. If it has still more than that, it begins to be conspicuously radioactive. * * *

"Matter then appears to be composed of positive and negative electricity, and nothing else. All its newly-discovered as well as its long-known properties can be thus explained—even the long-standing puzzle of 'cohesion' shows signs of giving way."

The most recent pronouncement may be found in an address on "The New Theory of Matter," delivered before the British Association for the Advancement of Science, by the Rt. Hon. A. J. Balfour, D.C.L., LL.D., F.R.S., M.P., president of the association.

Mr. Balfour says: "Surely we have here a very extraordinary revolution. Two centuries ago electricity seemed but a scientific toy. It is now thought by many to constitute the reality of which matter is but the sensible expression." Again he says: "To-day there are those who regard gross matter, the matter of everyday experience, as the mere appearance of which electricity is the physical basis; who think that the elementary atom of the chemist, itself far beyond the limits of direct perception, is but a connected system of monads or sub-atoms, which are not electrified

matter, but are electricity itself; that these systems differ in the number of monads which they contain, in their arrangement and in their motion relative to each other and to the ether; that on these differences alone depend the various qualities of what have hitherto been regarded as individual and elementary atoms; and that while in most cases these atomic systems may maintain their equilibrium for periods which, compared with such astronomical processes as the cooling of a sun, may seem almost eternal, they are not less obedient to the law of change than the everlasting heavens themselves."

Strange and incomprehensible as this electrical theory of matter may seem at first glance, it is, after all, but a modification of the vortex-atom theory, and it is incumbent upon us to realize that these new ideas, startling though they be, are not merely the imaginative inventions of scientific romancers, like Jules Verne, but are the serious thoughts of learned men who have delved deeply into original lines of research, and are recognized both as leaders of scientific thought and as eminent discoverers.

In conclusion, the speaker said that, although conscious of having imperfectly succeeded in his effort to elucidate so abstruse a subject as the modern conception of the nature of matter in the brief period of time available, he ventured, nevertheless, to hope that this little glimpse into the minute world of atoms and molecules might tempt his hearers to explore more deeply these interesting paths of knowledge, which have been so recently opened to view by toiling investigators who have taken the light of "pure science" for their guide, and have done much to enlarge the horizon of our mental vision and to expand our intellectual capacities.

CHEMICAL SECTION.

Stated Meeting, held Thursday, October 13, 1904.

Industrial Notes.

DR. BRUNO TERNE.

After an absence of nearly four years from Philadelphia, it affords me great pleasure to accept the invitation of my esteemed friend, Dr. Wahl, your Secretary, once more to address the Chemical Section of the Institute.

I can offer you no new discoveries, but I would like to call your attention, briefly, to some topics of technical chemistry which I have followed with special interest for years.

It is just about thirteen years ago (October 20, 1891) since I addressed this Section on the Utilization of the By-Products of the Coke Industry. We had quite an interesting and lively debate that evening.

Dr. H. W. Jayne said, in opening the discussion: "No one will deny the importance of the subject presented to us this evening, and I am aware that it has been carefully investigated by a number of large firms in the country, but as yet nothing has been done."

I took the broad view that no local interest, nor all the influence of all the gas-works combined, would be able to stop the development of the by-product coke-oven industry in this country.

My closing words in the records of this debate were: "The development of these industries is bound to come in spite of all opposition, nor will it be so far off. The right start is the most difficult point."

Now let us see where we stand to-day. It has been my personal good fortune to come in close contact through having business transactions with the present General Manager of the United Coke and Gas Works, Dr. F. Schniewind, the foremost leader of the modern coke-oven industry in this country, and by this means to follow the development of this industry step by step.

Dr. F. Schniewind represents the Otto system, whose patents are controlled by the United Coke and Gas Company of New York. The system has been greatly improved and made adaptable to the special wants of the different coal districts. We have one plant of this system in full blast on the other side of the river, in Camden, and a much larger one in operation at the steel-works at Sparrow's Point, Baltimore.

Interested parties will find no difficulty in getting permission to study these monuments of technical chemical engineering skill.

A close second to the expansion of the Otto system is the Semet-Solvay system, under the management of the Solvay Company, of Syracuse, N. Y. These two systems together have already made such progress that their output of by-products induced the parties controlling the output from the gas-houses to pool their interests and form a sales agency under the name of "American Coal Products Company," at 17 Battery Place, New York.

For fuller information on the statistics of this industry I refer you to the excellent essay of Dr. Schniewind, published in *Mineral Industry*, Vol. X, page 135, 1901–02.

The figures of the consumption and production of ammonia, as sulphate equivalent, for 1903 are as follows:

Imports.	Sulphate Equivalent.
Sulphate	16,770 net tons.
Muriate	2,813 "
Carbonate	2,636 "
Other forms	Insignificant.
	22,219 net tons.
Domestic Production.	
Coke Works, Gas Works, Carbon Plants	Estimated 40,000 net tons.
Total domestic consumption	about 62,000 net tons.

In the paper above referred to Dr. Schniewind estimates the production of sulphate of ammonia equivalent from the gas-works at 12,000 net tons. G. N. Parker, in *Mineral Resources* (1902), estimates the production at 15,641 tons.

Even if we allow the higher figures as correct and rounding up, allowing for the carbonizing plants with 17,000 tons, the sulphate of ammonia equivalent produced from the coke-ovens is 57½ per cent. of the total domestic output.

The increase of consumption has been, as compared with 1901, 14,178 tons, which mainly has been caused by the increase of the output of the coke-ovens.

To-day the Semet-Solvay Company has 650 ovens in operation in eight localities, and 120 ovens in course of erection.

The Otto system, represented by the United Coke and Gas Company, has 2,753 ovens in operation, with an output of 16,825 tons sulphate equivalent.

Taking these figures as a basis, they would leave for:

Gas-works	15,000 tons.	sulphate equivalent.
Otto system	16,825 "	
Semet-Solvay	8,175 "	
	40,000 "	

These figures may not be absolutely correct, but they are near enough to give you a true estimate of the relative proportion of the sources of ammonia production.

Thirteen years ago there was not a pound produced by the coke-ovens; to-day they yield from 25,000 to 30,000 tons per annum. This is only the beginning of the by-product coke-oven industries. At the present moment there is a stagnation in the steel industries, and consequently during the last two years very little has been done toward development of new systems. Those under contract have been finished or are nearly finished. This dullness will shortly disappear, and with the revival of the steel industry, the extension of the by-product coke-oven will go on step by step. The system has been firmly established, the prejudice against it proven by practical experience to be without basis, and the beehive oven will gradually be replaced.

I cannot help looking back to our meeting thirteen years ago with some satisfaction, knowing that I have been supported in my prediction by the actual facts of progress of which I have laid figures before you.

The production of coke may play an important part for domestic fuel, as well as for factories to help to minimize the smoke nuisance. The time is rapidly approaching when the home production of sulphate of ammonia, or its equivalent, will exclude importation, and further on will reverse the statistics of trade. The fear has been expressed that over-production would ruin the prices of the by-products to such an extent as to make the process unprofitable. There need be no fear on that score. Not only is the domestic market daily extending, but the foreign market also will, in the near future, come in with large demands.

The most powerful competitor of sulphate of ammonia in the broad field of the fertilizer trade is the nitrate of soda of Chili.

The source of this raw material is rapidly nearing complete exhaustion, and as nitrate of soda is consumed not only as a fertilizer, but also for other uses in the arts, it is to be expected that it will presently cease to play an important role as fertilizer material. Something else will have to take its place. The most available substitute is sulphate of ammonia.

You all know that a complete fertilizer must contain:

> Nitrogen, or its equivalent in ammonia;
> phosphoric acid in available form, and
> potash.

But all the different brands are wholly or partially mechanical mixtures, and the idea occurred to me, why should I use sulphate of ammonia in dry mechanical mixture, when I could make a better and cheaper compound of ammonia phosphate by using directly the ammoniacal liquors with the acid phosphate while in process of making it?

I made experiments on the manufacturing scale, and succeeded in producing a high-grade ammoniated phosphate at figures which will allow its profitable production. I secured by letters-patent, No. 709,185, the principle of the direct use of the ammoniacal liquors for this purpose. Without going into details, I will say that I have the endorsement of the leading agricultural chemists, as well

as the endorsement of the leading dealers for this product, of which I show you a sample.

Pending some negotiations, I expect presently to develop this process on a large scale, thus opening a new and direct use of the ammoniacal liquors of the by-product coke-oven in large quantities.

While I was engaged as chemical manager with several large companies for the utilization of garbage, and trying to improve the utilization of this material on a rational basis, I made experiments to produce the ammonia from it by destructive distillation.

In 1897 I communicated with Mr. R. M. Atwater, then secretary of the Semet-Solvay Company, Syracuse, N. Y. My suggestion was well received, and induced the Semet-Solvay people to make some preliminary tests in an experimental retort with material furnished by me. On the basis of these results, which confirmed my own, the Semet-Solvay people desired to make a large run in their regular coke-oven, for which purpose I furnished, from the Barren Island Works, a carload of pressed garbage.

At the time of working our material I was in Syracuse and witnessed the work, which was in charge of Mr. W. F. Blauvelt, now Chief Engineer of the Solvay Company, Syracuse.

The following is the summary of the report made:

The garbage was tested under various times of coking, and with varying percentages of moisture, with the result that there is no doubt that the full charge of 4 tons of dry garbage can be coked in twelve hours, or two charges per day. The average percentage of moisture in the garbage was 27·2. The total amount of garbage tested was 26,940 pounds, equivalent to 20,420 pounds of dry garbage. The maximum charge in any oven was 7,645 pounds. Total dry residue, 6,580 pounds, 32·3 per cent. of the moist garbage charged. The residue was composed of fine granular carbon mixed with bits of coking, wire, tin cans and other refuse material. Upon screening over ¼-inch screen, 26·5 per cent. coarse material remained. Of this screened material, 25 per cent. was carbon.

The yield of by-products is as follows:

Yield of ammonium sulphate per 2,000 pounds moist garbage, 61·3 pounds.
Yield of gas, 6,840 cubic feet.

ANALYSIS OF GAS.

	No. 1.	No. 2.	
CO_2	16·9	16·1	Carbon dioxide.
C_2H_4	0·0	0·7	Illuminating gas.
CO	37·0	28·7	Carbon monoxide.
O	·2	·6	Oxygen.
CH_4	7·6	10·5	Marsh gas.
H	32·8	36·	Hydrogen.
N	8·5	7·7	Nitrogen.
	100·0	100·3	

Total combustible, No. 1 = 74·7 per cent.; No. 2 = 75·2 per cent.

The results in the experimental retort were higher.

Sulphate of ammonia obtained by this test was 65·25 pounds for 2,000 pounds moist garbage.

The dry residuum was 43 per cent.

The large difference between the residue obtained in the retort and in the ovens is doubtless due to the amount left in the ovens after pushing, and the loss from blowing away and washing away with water while quenching.

It was now a matter of calculation to see if the higher yield of sulphate of ammonia could balance the lower yield of gas and the absence of coke as a marketable commodity.

The gas produced reaches within 1,000 cubic feet per ton of material. The gas production from an average bituminous coal will be sufficient to serve as fuel to keep the oven going without any extra fuel supply.

If the ovens are in proper order there will be sufficient surplus of gas to produce the steam required for the ammonia plant. The solid residuum contains sufficient phosphoric acid and potash to make it valuable as a fertilizing material, which, by mixing it with the concentrated tank-liquors, will be greatly improved.*

After going carefully over all these points and calculating closely in comparison with the older method, the New England Sanitary Product Company, of Boston, and the Semet-Solvay Company made an agreement the 22d day of April, 1898, to erect jointly a plant to take care of the garbage of the city of Boston with the production of ammonia by the

* See United States Patent No. 619,056, February 7, 1899.

adoption of the Semet-Solvay coke-ovens modeled for this purpose. The plant, which should have been ready in July, was not finished until late in the fall. It consisted of a complete system of seven ovens with all auxiliary apparatus for the production of ammonia liquors and sulphate of ammonia, with a capacity of 45,000 pounds for the ammonia department.

The general plant was designed by the engineer of the Sanitary Company, Mr. Charles Edgerton, of Philadelphia. The coke-ovens and apparatus pertaining to them were designed and built by the Semet-Solvay Company. A detailed description of this plant, with drawings, is given in the *Engineering Record*, September 14, 1901, page 251, by Mr. C. G. Atwater, who represented the Semet-Solvay Company at the Boston plant.

You will have noticed that the moisture in the material for the Syracuse test is a little lower than 25 per cent. This is lower by 10 per cent. than the average of the fresh material from the presses at that time in use at Barren Island. The press work was the most objectionable part of the utilization plants from a sanitary point of view, and it was the steady aim of the engineering force to overcome the nasty work of charging the old knuckle-joint screw process.

We have made numerous experiments with many different kinds of presses, with centrifugals of different styles, but not with success. Finally, Mr. Charles Edgerton designed a roller press which, from a sanitary point of view, overcomes all objections, and as a labor-saving device cannot be excelled; but it had one great fault—it did not give the same result either in moisture or in grease.

In eleven tests which I made from December 10 to 31, 1898, the result was:

Moisture	52·38
Grease	5·84

In January, 1st to 7th, stock taken from storage on top of the oven ran as high as 62·84 per cent. moisture. This excess of moisture was death to the work of the ovens. We simply could not keep up the heat in the ovens; the retorts were changed to boilers. It takes not much argu-

ment to convince any one that under such conditions the ovens could not give satisfactory results. It was a most deplorable condition of circumstances that the introduction of the new presses absolutely spoiled the well-calculated work of the ovens.

The condition in Boston was such that the award of the contract depended on the performance of the new press, and there was nothing left to be done but to try to improve the work of the press to reduce the moisture, but it seemed absolutely hopeless to reduce the moisture to much less than 50 per cent.

We went to the limit to close the presses down, but we could not afford to keep it up—first, because the rollers would not get sufficient material through; and second, the breakage of the driving gears was so bad that it would have necessitated a special machine-shop and foundry to keep us going. Under these circumstances we came to the conclusion to put up a revolving drier, heated with the waste heat from the boiler, to improve the condition of the pressed garbage. After much loss of time we succeeded in reducing the moisture to such a degree that the ovens commenced to show results, and we accumulated ammoniacal liquors, which gained in strength from day to day. Improvements in the gearing of the presses at the same time helped to get a better raw material, and supported the drier in its work. Everything pointed to the way of final success. We had filled our weak-liquor storage tanks, and commenced to concentrate for shipment. We had made several hundred tons of fertilizer ready for the market when fate threw us down and out.

On the morning of February 10, 1899, a disastrous fire destroyed the plant. The whole by-product plant, with the exception of the ovens, lay in ruins, and therewith ended the chapter of our attempt to utilize the coke-ovens for the utilization of garbage, at least for the time being. But by no means had our well-calculated plan, based on a different condition of the raw material, been proven to be incorrect. It was the one change in the condition of the raw material which caused all the annoyances and delays, and it was this point which frustrated the rebuilding of the plant.

Rather than go on again under the same conditions, the Solvay Company accepted their loss and canceled their contract. The plan to utilize the coke-oven product for the utilization of garbage is to-day as correct as when we made the tests in Syracuse, but the material must be of the same consistency as that which I sent to Syracuse.

The roller-press, even to-day, is not an efficient machine because it does not give sufficient pressure, and also leaves too much moisture and grease in the product. As I said before, the press works clean, it creates the least nuisance, it takes fewer men to work it, but the product cannot be compared with the product of the hydraulic presses at work with the same material at Barren Island and Philadelphia.

If the ammonia market is favorable, pressed garbage with 25 to 30 per cent. of moisture will form a good raw material for its production. I would, if I should build another plant, modify the system of horizontal retorts to vertical ones, as both charging and discharging can be more easily arranged and the loss of material in discharges greatly reduced; the material should come from the presses by all means with no more than 30 per cent. moisture, which can then easily be reduced 10 to 15 per cent. more before entering the retorts.

There is a disposition among the large companies controlling the utilization of garbage to be satisfied to produce only grease and allow the rest to go to waste. An exception is the Barren Island plant, where the fertilizer is made in both conditions, improved with the tank liquors or in the original state. The plants in Boston and Philadelphia either sell the pressed garbage or use some under the boilers for fuel. In either case it is a waste, and the plant is not worked as it should be.

It is a miscalculation to lose the fertilizer; all figures to the contrary are based on wrong premises. It is certainly easier to handle, but it is incorrect and not to the manufacturers' interest to throw away these products for which there is a large demand.

I may be allowed to make one more remark about the peculiar ideas in existence regarding the garbage business.

There is annually a great outcry in Philadelphia when the contracts for the following year have to be given out. We are going through this again, and the newspapers have an easy time filling their columns. As usual, some one is kind enough to help them out by making some nonsensical proposition.

The most nonsensical error made in this proposition is, to pay for each ton of garbage, delivered to an imaginary plant, $1 per ton to the city. I take from the *Ledger* clippings the following figures:

The writer places the total number of tons of garbage collectable at 380,000 tons per annum; this means 1,200 tons per day of 300 working days. There are not 500 tons a day to be found in Philadelphia; the whole case is built on talk of the wildest kind, and with it the whole calculation falls like a house of cards. It is only surprising how the Department of Public Works, which has access to the statistics of the works, can be led astray by such wild talk of imaginary profits and give color of approval to it by their vacillating action.

The utilization of the garbage of our great cities can be the basis of a well-paying business if the material is brought to the works free of cost; the gathering of the material is a department of this business which must not only be self-sustaining, but should show profit in itself. The products possible must all be made in the most economical way; but there should not be for manufacturing reasons a break in the chain. The more complete the yield of marketable products is made, the larger the profits. If, at the beginning of new enterprises—like the whole garbage industry—obstacles common to all new enterprises have to be overcome, they have already, for the largest part, been met successfully, and should by all means, by steadily improved methods, be overcome without difficulty.

The fertilizer produced from garbage, while only of a low grade, 3 to 4 per cent. ammoniacal tankage, has a wide field in the trade because of its physical qualities, as an excellent filler and for which there is a great want. The farmer who spreads his fertilizer over a large area likes to

have a large volume to work on. At the same time the demand is for a low-priced product. Consequently the manufacturer of fertilizer must look for material which fills the double requirement of "cheapness and volume." Nothing can fill the bill better than the garbage tankage.

It is to be hoped that the former policy of using everything will be restored where it has been suspended. The demand for cheap tankage has caused the utilization of other waste material such as cheap manure products, etc. In Illinois, in the center of the corn-belt, where the great distillers are situated, in Peoria and Pekin; in Terre Haute, Ind., and other places, the feeding of cattle forms an important factor for disposing of the waste from the distilleries. In the stables of Peoria and Pekin there are from 20,000 to 30,000 head of cattle. You can imagine what a quantity of manure material the animals produce. So far all this material goes to waste and simply helps to contaminate the Illinois River.

While St. Louis is trying to control the Chicago Drainage Canal, claiming that the contamination of the Mississippi River is caused by it, they would better look further down the river and examine the water above and below Pekin–Peoria before pressing their fight against the drainage canal.

I was lately interested in an attempt to utilize the stable offal for the manufacturers of sulphate of ammonia and manure tankage in Pekin, Ill.; this attempt, however, was unsuccessful.

It is a very nice problem in technical chemistry which can without doubt be solved financially, if the necessary capital for the right equipment *is forthcoming at the start.*

In the atmosphere surrounding our globe we have an inexhaustible source of nitrogen, but we have thus far failed to make these riches serviceable to the cultivation of our soil. It seems now that we are in a fair way to accomplish this object in a practical way by two entirely different modes of procedure.

Numerous attempts have been made without practical results, but at last the work of the electric furnace seems to be on the point of being successful.

I will read to you an abstract from a recent report of F. H. Mason, U. S. Consul-General at Berlin:

NEW ARTIFICIAL NITRATE.

The gradual but ultimately inevitable exhaustion of the known nitrate deposits of South America lends a growing interest to the methods which have been devised for obtaining a supply of nitrogen for fertilizing purposes from the inexhaustible storehouse of the air. That this can be done as a scientific process has long been known. The first method was by passing a current of air over red-heated copper, whereby the oxygen combined with the metal to form oxide of copper, leaving the nitrogen free. At first the nitrogen thus produced was fixed by combination with calcium carbide to form . . . (Kalkstickstoff) or calcium cyanimide, a combination of lime, carbon and nitrogen, which had all the essential properties of a nitrate fertilizer. But as the use of calcium carbide rendered the product unduly expensive, a method was sought which would employ a substitute for that material, and this was found by Dr. Erlwein, who brought the nitrogen into combination with a mixture of powdered charcoal and lime in an electric furnace. The product of this combination is a black substance containing, besides the lime and carbon, from 10 to 15 per cent. of nitrogen in perfect condition to be used as a fertilizer. From the experiments thus far made with this new article—which is known in commerce as calcium cyanimide—it appears that its nitrogen acts upon plants quite as effectively as that contained in a proportionate quantity of nitrate of potassium or sodium nitrate (Chili saltpeter). The scientific problem of obtaining nitrogen for fertilizing purposes from the atmosphere would seem, therefore, to be satisfactorily solved. Whether it can be done on a very large scale and at a cost which will make it economically available for general agricultural purposes remains to be demonstrated by practical experience.

I have not been able, in the short space of time allowed for the preparation of these notes, to find specific reports of the work of Dr. Erlwein so as to form an idea of the practical success of this process. The wonderful success of the electric furnace in other branches of applied chemistry permits us, however, to anticipate the solution of this problem also, and we may not unreasonably hope for the successful production of artificial nitrate in the near future on a practical basis.

Ever since the soil has been cultivated the farmer learned to know that after a crop of leguminous plants, such as beans, clover, peas, etc., the soil seemed to be benefited by it; not only that these plants required less fertilizer than others, but also that they directly helped to fertilize the soil for the succeeding crops.

Based on this experience, a rotation of culture has been established, and is used by every intelligent farmer. It is only recently that the reason for the beneficial action of these plants has been clearly established.

The investigations of Dr. Fr. Nobbe, a noted agricultural chemist, of Germany, were the first to call attention to the fact that the peculiar formation of nodules or tubercles on the roots of these plants was due to the action of innumerable bacteria, and that, unless these tubercle bacteria exist, the plant is no more able to fix the nitrogen of the air than any other plants which do not have such nodules on their roots. This fact established, it was the aim to cultivate such microbes to insure the formation of the tubercle.

Several years ago German investigators put upon the market a product known as nitragin, which purported to be a pure culture of the root-tubercle organism.

The results, however, were disappointing. In a few instances, in Germany, excellent results were obtained, but in the majority of cases the crop was not better than without inoculation. The preparations of nitragin were sold in bottles prepared for each different crop. The result here, with the nitragin imported, was still worse; fully 80 per cent. of the culture turned out to be a failure. The nitragin has now disappeared from the market. The failure to give permanence to the microbes in the fluid preparation was the reason of the uncertainty in its application to the soil. At this juncture the Laboratory of Plant Physiology of the Bureau of Plant Industry in Washington took up the research. It was soon found that the method in use by the German investigators was not adapted to maintain the life of the organism; that is to say, the use of nitrogenous food material, such as decoctions of the host plant, was not calculated to produce an organism which would fix free nitrogen from the air.

It was found that, while the bacteria grew luxuriantly upon such media, they became less and less active, until eventually they lost completely the nitrogen-fixing power. It seemed as though the large amount of nitrate in the media upon which they were grown made it no longer

necessary to draw nitrogen from the air. It was found, however, that by gradually reducing the amount of nitrogen in the culture medium it is possible to greatly increase the nitrogen-fixing power of these germs, and that by proper manipulation this may be increased from five to ten times that which usually occurs in nature.

The attainment of these remarkable results is the work of Dr. George T. Moore, in charge of the Laboratory of Plant Physiology, U. S. Department of Agriculture. They place him in the front rank among plant physiologists and as a benefactor to mankind. With unexampled liberality he has given the results of his researches for free use by the farming communities of the United States.

He filed a patent application May 4, 1903, and letters-patent were granted to him March 22, 1904. The patent is of such importance and gives so clear a description of the process that I introduce it as part of this paper.

UNITED STATES PATENT OFFICE.

No. 755,519. Patented March 22, 1904.

George T. Moore, of Washington, District of Columbia.

Process of preparing for distribution organisms which fix atmospheric nitrogen.

Specification forming part of letters-patent No. 755,519, dated March 22, 1904.

Application filed May 4, 1903. Serial No. 155,695. (No specimens.)

To all whom it may concern:

Be it known, That I, George T. Moore, a citizen of the United States, residing at Washington, in the District of Columbia, have invented new and useful improvements in the process of preparing for distribution organisms which fix or gather atmospheric nitrogen, of which the following is a specification:

This application is made under the Act of March 3, 1883, Chapter 143, and the invention herein described and claimed, if patented, may be used by the Government of the United States or any of its officers or employees in prosecution of work for the Government or by any other person in the United States without the payment to me of any royalty thereon.

The invention relates to the process of growing these organisms and preparing them for distribution.

The invention has for its object the production of more highly effective organisms and their distribution in a form preventing deterioration, and easily applied in agriculture. All work that has heretofore been done in the cultivation of nitrogen-gathering root-tubercle organisms for use in agriculture has been done in culture media containing either decoctions of the leguminous

plants, from which these specific organisms in each case were obtained, or in media containing some other available form of combined nitrogen not free or atmospheric. When there is available combined nitrogen in the medium, the organisms, instead of depending solely upon the atmospheric nitrogen for their nitrogen supply, draw upon the nitrogenous materials of the culture medium, such, for example, as proteids, nitrates, ammonium compounds, etc., for which reason they do not develop their full nitrogen-gathering power and rapidly deteriorate.

By my process the organisms are first obtained from the tubercles or swellings on the roots of the leguminous plants, such as clovers, cow peas, beans, etc. After the tubercles are thoroughly washed and surface sterilized in the ordinary ways, the interior of the tubercle is cut out under sterile conditions and mixed in a medium consisting of water containing about 1 per cent. commercial agar-agar, about 1 per cent. maltose sugar or cane sugar (the former being the better), about ·02 to ·05 per cent. magnesium sulphate and about 0·1 per cent. monobasic potassium phosphate. This solution is made up in the ordinary way, and sterilized according to ordinary bacteriological processes. It differs from ordinary culture media for bacteria only in the absence of a source of combined nitrogen. The agar may be varied above or below the amount suggested. The maltose or cane sugar may be increased to 10 per cent., the magnesium sulphate to 1 per cent., the monobasic potassium phosphate to 2 per cent., or the amounts may be lowered below the quantities first mentioned. In the latter case, however, the food materials are more quickly used up. The organism multiplies as long as the materials in solution are not exhausted. Other compounds may be used as sources of magnesium, potassium and phosphoric acid. Although I usually leave nitrogen out of the culture medium at this stage, its absence is not essential, as the object of the first step is simply to separate the organisms into pure cultures, free from mold or other contamination, the process of separating out in this fashion being familiar to all bacteriologists and in common use. They grow best between 20° and 30° C., and light or its absence is immaterial. When pure cultures are thus obtained, the organism is transferred immediately, or after several weeks, if desired, by any of the bacteriological transfer methods in use, to water containing about 1 per cent. cane sugar or maltose (the latter being the better), about ·02 to ·05 per cent. magnesium sulphate and about 0·1 per cent. monobasic potassium phosphate, or equivalent sources of magnesium, potassium and phosphorus, as in the case of the first-described medium. The quantities used may here also vary, as stated above; but the per cents. given have been found to be the most favorable for growth under ordinary conditions. One cubic centimeter of the culture will suffice for impregnating 100 liters of the fluid. Any kind of container or vessel that can be easily cleaned will serve for this purpose; but Erlenmeyer flasks are best where small quantities are to be cultivated under antiseptic conditions. In this solution, which should be kept between 20° and 30° C., in light or in darkness, as desired, the organisms increase very rapidly, and have to obtain all of their nitrogen in the free state from the atmosphere or from the atmospheric nitrogen in solution in the medium. This liquid culture solution, even when in large quantity, will in a few days become milky in appearance by the presence of immense numbers of the developing organisms. The

water containing the organisms, where direct use is desired, is then sprinkled upon seeds or soil; but for the purposes of preservation and distribution the following steps are taken: Absorbent cotton or other equivalent material is dipped into the water containing the organisms, or the water containing the organisms is sprinkled upon the cotton or other material, and the same thoroughly air-dried in a chamber free from dust or contamination from molds. The drying is facilitated by forcing a current of air through the chamber by aspiration through sulphuric acid, potassium hydroxide, sodium hydroxide or any of the other ordinary materials used in laboratories for drying. In this dry form the organisms may be kept indefinitely without deterioration or change, and may be safely, easily and cheaply transported to any distance, either through the mails or otherwise. In using the organisms preserved as above described the dry absorbent material containing them is simply dropped into a water solution of the same composition as above described. Where the purpose is to treat soil or seed, it is not necessary to observe strictly antiseptic precautions. Ordinary clean vessels or tubs may be used, simply protected from dust, and ordinary well-water or rain-water is used in making the culture solution, as the amount of nitrates or ammonia which such waters ordinarily contain does not interfere with the vitality of the organisms at this stage of the process. The temperature and light conditions should be as previously stated. In from twelve to forty-eight hours the organisms will have increased in the water culture, as in the first instance. At this stage, in order to stimulate a very rapid division of the bacteria, about 1 per cent. phosphate of ammonia is added to the culture solution. The quantity of liquid culture that may be thus obtained is limited only by the amount of water used containing the sugar, magnesium sulphate and potassium phosphate or other equivalent sources of magnesium, potassium and phosphorus, as above described. After thus obtaining the liquid culture, it is then necessary only to sprinkle the seeds or soil to be treated with water containing the organisms, or to dip the seeds into water containing the organisms, and then dry them in the ordinary way to facilitate planting. The propagation of the bacteria should not be continued longer than from twelve to forty-eight hours after the addition of the phosphate of ammonia; otherwise they will deteriorate in nitrogen-fixing power, as previously explained, and organisms thus stimulated should be used only for seed or soil impregnation, and not for preservation or distribution.

Having thus described my invention, what I claim, and desire to secure by letters-patent, is:

The process of preparing for distribution nitrogen-gathering organisms, which consists in moistening suitable absorbent material with a solution in which such organisms are suspended, and afterward thoroughly drying the said material substantially as hereinbefore described.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

(Signed) GEORGE T. MOORE.

Witnesses:

(Signed) A. F. WOODS,
GEO. P. MCCABE.

The Department of Agriculture, recognizing the importance of this investigation, has set out at once in the most practical way to make it possible for any progressive farmer to reap the fruits of this discovery, and make his barren land serviceable. For full information I refer to the "Year Book of Agriculture" for 1902, and in more popular form to the October *Century Magazine*. Through the kindness of Prof. H. W. Wiley I received a day ago a sample of the material as sent out by the Department, which I have now the pleasure to present to you.

The practical results achieved in the short time since the development of this industry of our Agricultural Department are of inestimable importance to the farming interests of our land. The cultivation of the nodule-producing bacteria and their preparation for distribution the world over without deterioration is a wonderful discovery. The first attempt to make the nitrogen of the air serviceable to the cultivation of the soil has been successfully made. Although limited to the cultivation of leguminous plants, it is of invaluable benefit to all crops by their judicious rotation.

As the experiments with the electric furnace to utilize the nitrogen of the atmosphere indicate coming success, and with the assurance of a steady increase in the production of ammoniates by the coke-oven process, and the utilization of all organized ammonia sources, we need not fear that the exhaustion of the South American nitrate beds will injuriously affect the fertilization of our land with nitrogen.

It has always been, and will always remain true, that as one material is exhausted it will be replaced by the utilization of others.

ELECTROLYTIC CONVERTER.

In certain branches of Röntgen-ray work, particularly in the medical department it is desirable to secure very rapid pulsations of the current, and also to provide an interrupted direct current instead of an alternating current. For this purpose, W. B. Churcher makes use of the ordinary Röntgen-ray bulb connected to the well-known induction coil, but as a source of interrupted current for the primary of the coil he employs a special type of electro-

lytic converter, for which a patent was granted to him August 9, 1904. The cell, of which the electrolyte is preferably sodium or potassium phosphate, contains three electrodes, two of aluminum and one of some metal not easily attacked by the electrolyte, such as platinum or gold. The aluminum electrodes are connected directly to the outer leads from an alternating-current transformer, while the two primary terminals of the induction coil are connected respectively to the neutral point of the transformer coil and the third (gold or platinum) electrode of the cell. Under operating conditions the third electrode will be positive to one of the aluminum electrodes and negative to the other at either phase of the current. The nature of aluminum in an electrolyte is such that only negative current will flow from the platinum or gold electrode to whichever of the aluminum electrodes happens to be positive thereto. The interruptions of the current, other than what are due to the alternators of the supply system, are produced by reason of the small surface of the platinum or gold electrode which is exposed to the electrolyte, and at which, upon passage of the current, there is produced gas in sufficient quantity to insulate the electrode and interrupt the current.—*Electric World.*

PROFESSOR PICKERING'S REPORTED LUNAR CHANGES.

Prof. William H. Pickering, now temporarily located at the Lowe Observatory, Echo Mountain, California, reports that on the night of July 31, 1904, a bright, hazy object 2 sec. in diameter was noticed upon the floor of the lunar crater Plato. Observations made July 21st, 22d, 23d, 26th, 27th and 28th had shown nothing unusual at this point. August 2d in place of the bright object a black elliptical shadow was seen. It resembled a crater, and measured about two miles in diameter. To the northeast and north extended a large white area. This was confirmed upon August 3d. The object coincides approximately in position with craterlet No. 3, "Harvard Annals," XXXII, Plate X. A telegram dated August 22d confirms the reality of a conspicuous change in this region since last month. It states that the existence of the new craterlet is confirmed, that its diameter is three miles and that the bright area had shifted obviously since August 3d. Several other objects not previously mapped have been observed while examining Plato. They consist of two craterlets and a dark spot between two rifts on the southern border of the crater floor, a large craterlet on the northeastern border and another one 2 sec. southeast of craterlet No. 68. The white area formerly so conspicuous surrounding craterlet No. 54 has almost disappeared.—*Scientific American.*

STEEL TIES AT HOMESTEAD STEEL WORKS.

For some months past the Carnegie Steel Company has been making railroad steel ties in an experimental way at the Homestead Steel Works. Recently a cheaper method of rolling these ties has been found, and the prospects are that the tonnage will be materially increased. The large amount of electric railroad building has proved a good consuming field for the railroad tie. During the coming winter it is expected that the output of steel ties at the Homestead Steel Works will be materially increased.

The Jones Underfeed Stoker.

[*Report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of Evan William Jones.*
Sub-Committee: Kern Dodge, Chairman; John W. Hartman, James Christie, H. F. Colvin.]

[No. 2283.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the merits of the "Underfeed Stoker," by Evan William Jones, of Portland, Oregon, reports as follows:

Mr. Evan William Jones, while working on the problem of successfully burning Oregon fir, invented the first form of the device under consideration. The Oregon fir is extremely difficult to burn on account of its retention of a large proportion of moisture, and he found that this trouble could satisfactorily be overcome by supplying the wood from the bottom, thereby using the green fuel as grate bars for the pieces in combustion.

The first arrangement built by Mr. Jones was hand-operated, and the sticks of wood, in standard lengths of about 4 feet, were forced in by means of a system of levers. In this way the fundamental principle was proved to Mr. Jones' satisfaction to be correct, but the hand device was not an economical way of charging the furnaces, so he adopted the steam cylinder and ram for forcing the wood into place. The device proved entirely practicable, and was used successfully in a number of plants in Portland and vicinity for a number of years. These wood-burning grates were first operated about the year 1889. Not long after their successful operation it occurred to him that the field for a mechanical stoker, designed solely for the use of wood for fuel, was very limited, and, on account of high proportion of volatile matter obtained from bituminous coal, he turned his attention to the perfection of a mechanical stoker, using coal as fuel.

He was convinced that the fundamental principle of underfeeding was a success, and that the introduction of

the air above the fresh, or green, coal, but below the incandescent bed of fuel, would give a thorough mixture of the gas and air before reaching the zone of combustion, as the gases are driven from the green coal at about this point. This results in a practically complete combustion and the utilization of the heat of these gases, which in hand-firing is, to some extent, lost. At about this time permission was granted by the authorities of the Portland Cable Railway Company, Portland, Oregon, to equip two of their furnaces with this type of stoker, these being the first, using coal as fuel, to be put in practical operation. Several improvements and developments have since been made, but the fundamental principles were all set forth in these two stokers.

The coal in the underfeed type of stoker is thoroughly coked before it reaches the zone of combustion, and it is interesting to note, in this connection, that in the history of mechanical stoking attention was first called to the use of the progressive burning of coal by James Watt. He distilled the coal on a dead plate at the mouth of the furnace, and then pushed the coke back over the grate area by hand. In this way fairly good combustion can be obtained, but the labor is excessive. The first mechanical stoker was patented in 1841, by John Jukes, an English inventor. This was of the tread-mill type, now known as the chain-grate stoker, there being several makes on the market to-day of this general type.

In the Jones stoker the coal, being forced in below the bed of fire, causes the entire bed to move with each charge, so that the fresh coal is continually breaking up the surfaces of the bed, and tending to build the mound higher, causing the clinker and ash to roll off the top of the burning mound to dead plates on the sides, where they can be removed from fire doors at convenient points.

With certain grades of coal (the so-called fusing or clinker kind) trouble has been experienced in some stokers in the handling of the clinkers; but where such coal is to be had, good results can generally be obtained by mixing the coal with some other good kind, the percentage of good coal required being, as a rule, comparatively small.

Many objections have been raised to stokers in general on account of their not being able to respond quickly to variable loads, but we do not find ground for these objections in the underfeed type, where the forced draft may be increased, and the stoker operated more rapidly at will. In many cases this is taken care of automatically by the engine which drives the blower and operates the stoker valves, as the engine can be equipped with a regulating throttle valve, so that with a decreased steam pressure an increased amount of steam is allowed to pass to the engine, thereby increasing the blast pressure as well as the speed of charging the fuel. If the stokers are properly operated, no trouble should be experienced in regard to taking care of variable loads, as has been definitely proved by many users.

There have been many so-called total failures of mechanical stokers and, of course, there have been many invented which were not at all practicable, but many times stokers are condemned on account of matters which have no bearing on their construction or operation. Stokers have, in some instances, been condemned when the only trouble was that the fire did not have the proper draft on account of a stack insufficient to give ample draft, or a flue so constructed that the draft is almost entirely shut off. We have heard of one instance of stokers condemned because the damper lever on the flue was not placed parallel with the damper, so that the draft was cut down by having the damper partially closed. When stokers fail to operate properly, all these details should be looked into before they are condemned. In many cases the stoker is placed too close to the boiler tubes and the gases do not have sufficient time to properly ignite before they are chilled by coming in contact with the tubes.

The above is, of course, quite general, but we will now turn to the details of the apparatus under consideration.

Fig. 1 illustrates the stoker complete with the steam cylinder and ram, coal hopper, retort and all the details which go to make up a complete device.

This view shows the pusher rod extending from either

end of the retort and its connection with the ram and steam valve shown beneath the hopper. This pusher rod will be better seen in the next illustration.

Fig. 2 clearly shows the position of the tuyere blocks in relation to the retort, and also the pushers and pusher

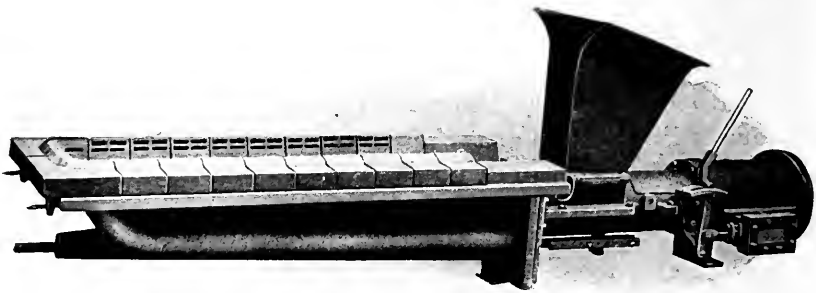

FIG. 1.—Jones under-feed stoker complete.

FIG. 2.—Retort of Jones under-feed stoker showing pusher rod and tuyere blocks.

rod in the bottom of the retort. The object of these pushers is to aid in pushing the coal to the rear of the retort, so that the entire bed will rise evenly. The position of the pushers can be adjusted, as well as the stroke of this pusher rod, independently of the length of stroke of the ram, which is

always operated at full stroke. In the illustration there will be seen, on the left, two handles; these are rods which lock the tuyere blocks into place. The scheme of fastening is better illustrated in the next cut.

Fig. 3 shows the under side of one edge of the retort with some of the tuyere blocks in position and others which are not. The tuyere blocks are locked in position by the rod which runs through the lower projection on each. By withdrawing this rod all the tuyere blocks are loose and may be removed. It is not necessary, however, to renew these blocks often, and we have records of instances where

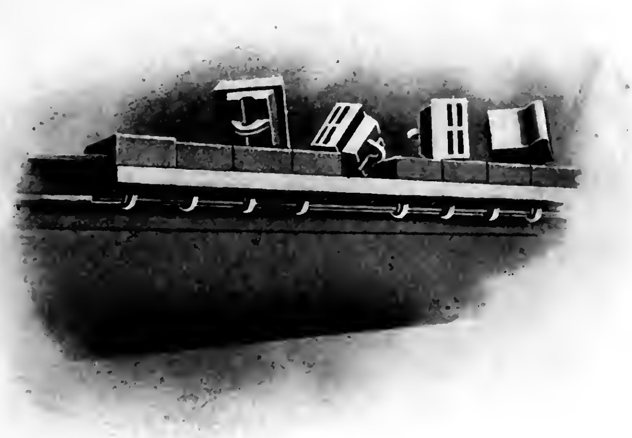

FIG. 3.—Method of attaching tuyere blocks.

they have been in continual use for long periods without being seriously impaired.

Fig. 4 shows the part of the device which is outside of the boiler front. The retort, tuyere blocks and parts illustrated before, are, of course, on the inside of the boiler front under the boiler. The outside parts consist of a steam cylinder, ram case and ram for the coal, and a hopper from which the coal flows by gravity into the ram case. This hopper may be filled by hand or coal may be delivered to it by means of chutes from overhead coal bins, depending upon local conditions. Beneath the ram case the outer end

of the pusher rod may be seen; at this point it is separated into two plates with a series of opposite holes in them. A projection from the ram through the bottom of the ram case

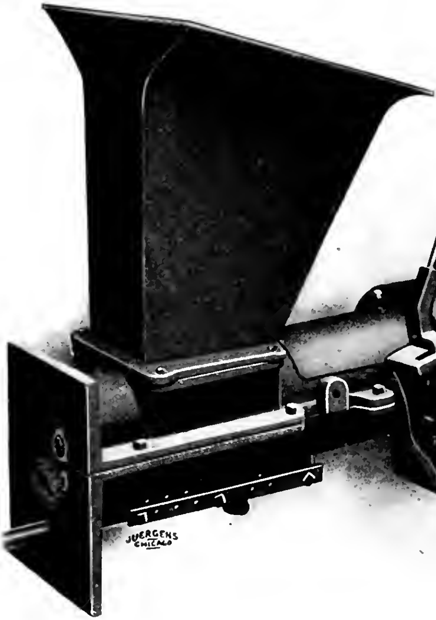

FIG. 4.—Cylinder, ram case and hopper.

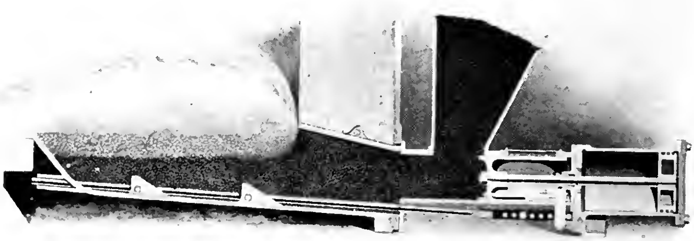

FIG. 5.—Jones under-feed stoker in operation.

engages the pusher rod by extending between the two plates which are attached to the pusher rod. The position of the bolts in the holes of these two plates determines, necessarily, the length of stroke of the pusher rod, as the projection

from the ram can travel between these two plates until it strikes the bolt which has been set in any desired pair of

FIG. 6—Cross-section of boiler and stoker.

holes. The ram is operated in this case by hand, the handle being clearly shown. To this handle is attached the valve stem of the steam chest on the cylinder, and the *D*

slide valve is moved across the ports by this hand lever, thereby admitting steam to the cylinder at either end.

Fig. 5 illustrates the complete stoker installed and in operation, showing clearly the position of the various parts and their relation to each other. The coal ram and the steam piston are connected to a common piston rod, as shown, and the arrangement is in all respects extremely simple. By moving a bolt, the stroke of the pusher-rod may be varied. The mound of incandescent fuel is shown above the retort.

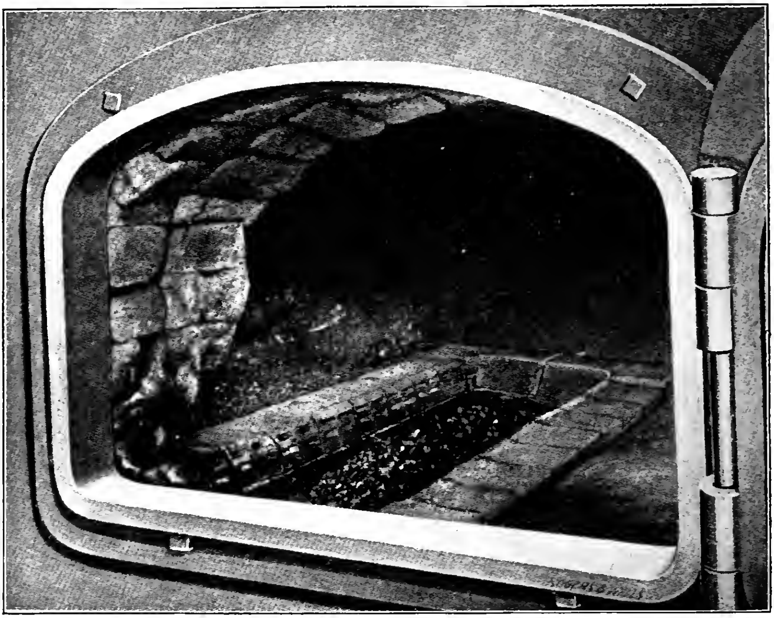

FIG. 7.—View through fire door showing retort.

Fig. 6 shows a cross-section of a return tubular boiler with stoker in operation. This illustration shows the blast pipe from the low pressure blower at the bottom, opening into what would be the ash space if the boiler was hand fired, and the relative position of the tuyere blocks, green coal and incandescent bed of fire. The dead plates are seen on either side of the retort.

Fig. 7 is a view is taken through the fire door of a boiler showing a retort which has been in operation. The coal

has been removed so that the tuyere blocks and their condition may be seen.

In *Fig. 8* will be seen five boilers in the plant of the Milwaukee Street Railway and Lighting Company, each

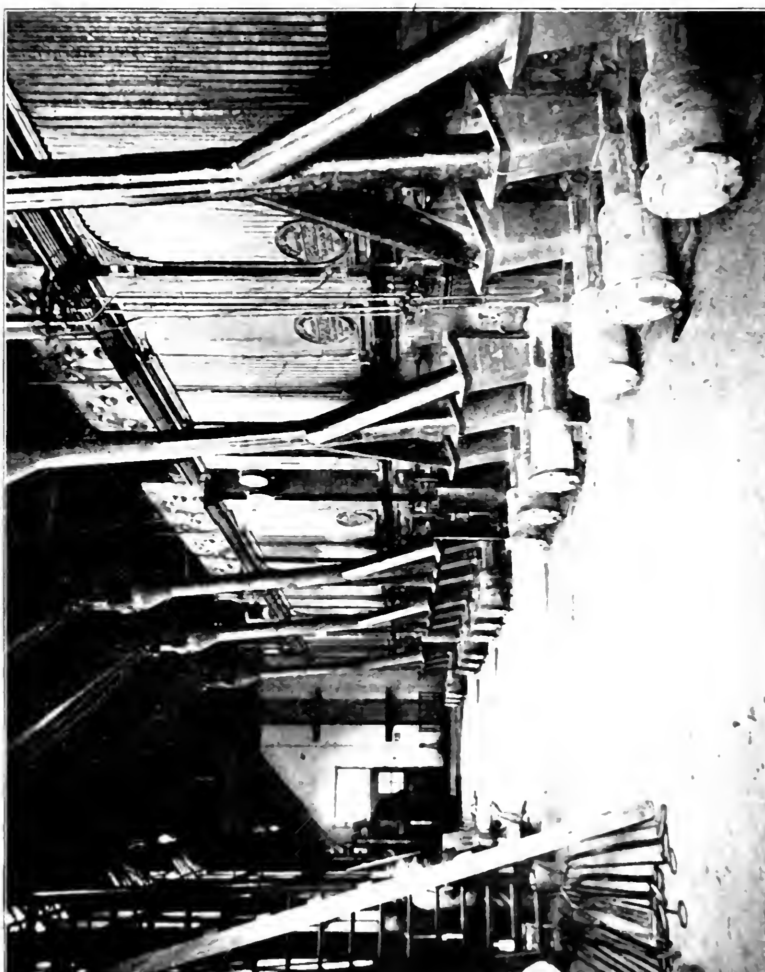

Fig. 8.—Milwaukee street railway and lighting company's boiler plant.

equipped with three Jones stokers. This particular installation is operated by an automatic device which is of the same principle as that illustrated by *Fig. 10.* The steam and oil cylinders are enlarged so that a single attachment is of sufficient capacity to operate three stokers instead of

one. This is accomplished by means of a shaft connected by a bell-crank to the piston of the automatic attachment. In this plant are seen the coal chutes for charging the stokers and the coal hoppers overhead; by this means all

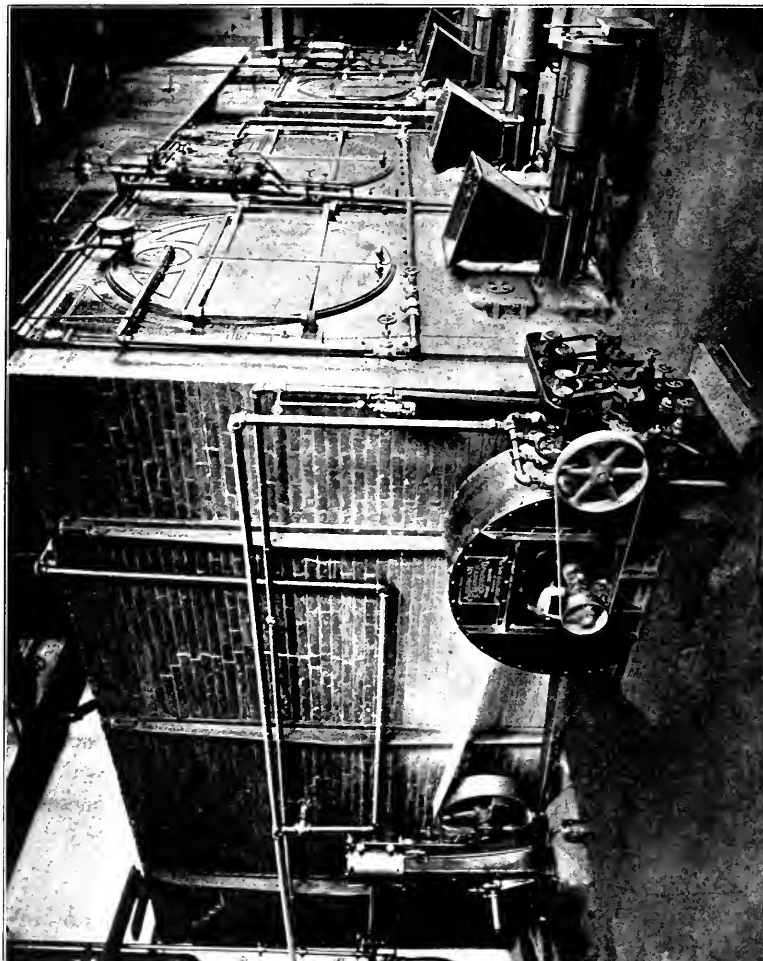

FIG. 9.—Engine blower and Cole automatic.

handling of the coal by hand is done away with, and considerable labor is thus saved.

On the right-hand side of *Fig. 9* the stokers are seen installed, and it will be noticed that they have no steam chests on their cylinders. In the center of the picture is

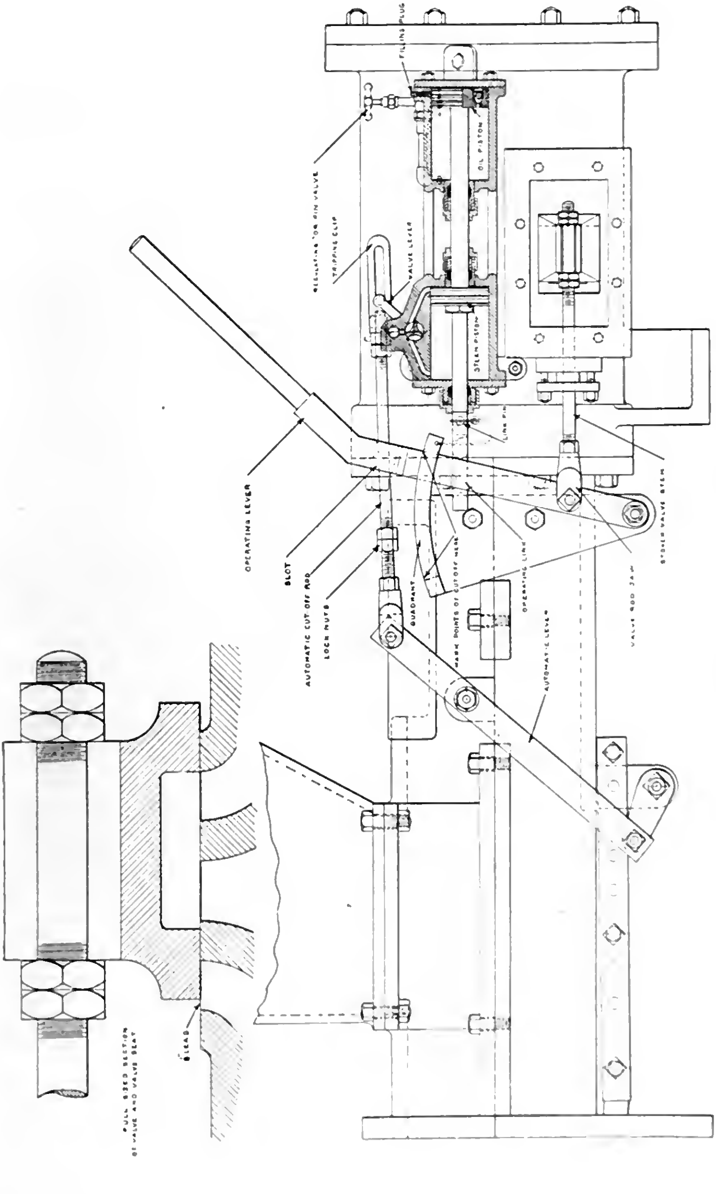

FIG. 10.—Automatic pump attachment on stoker.

the blower; directly in front of it is the automatic device which operates the stokers. This device is operated by a belt to the blower shaft, as shown.

It will be noticed that near the top of this device and on the front there are four gear-wheels with a *T*-slot groove across their faces and *T*-head bolts, which can be locked in

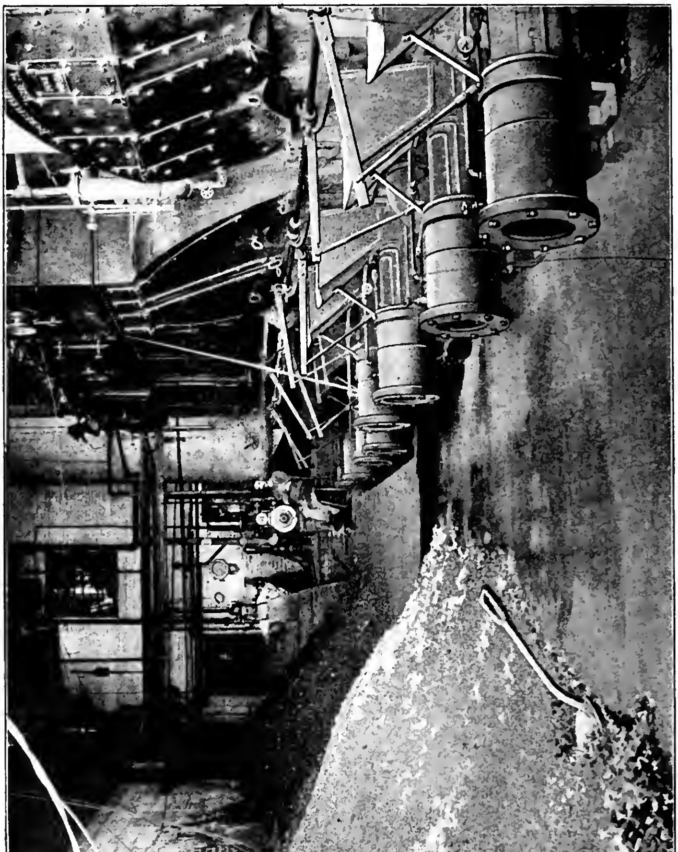

FIG. 11.—Jones stoker showing automatic crank shaft operating device.

this slot by means of the hand-wheel. On the shank of this bolt connecting rods are attached, which lead down to the valves below. Each of these valves control one stoker, and the valve, in making a complete cycle, alternately forces the ram of the stoker in and back to its charging position. The

amount of throw on these valves can be regulated by adjusting the *T*-head bolt in the slot of its gear, and the speed of the entire system is varied according to the speed of the engine, which is, in turn, controlled by the pressure of the boilers.

In *Fig. 10* there is a small independent pump attached directly to the stoker cylinder, which has a steam end and an oil end. The steam is admitted alternately on one side and then on the other of the steam piston, and the speed of this piston is regulated by a by-pass valve on the

FIG. 12.—Eccentric shaft operating stokers.

oil cylinder. The piston rod of this pump engages the hand-lever of the stoker, and operates it in the same manner as it would be operated if by hand. The speed then of charging is regulated by the small by-pass valve on this independent pump.

We have in *Fig. 11* the boiler-room of the Bausch & Lomb Optical Company, Rochester, N. Y., and, as will be seen, there is a crank shaft across the front of the boilers and connecting rods from the various cranks to the operating handles on the stokers. The coal in this plant is shoveled by hand into the hoppers of the stokers, as shown.

In illustration *Fig. 12* the stokers are shown operated by means of a shaft beneath the ram case, which has eccentrics on it at each stoker. To these eccentrics connecting rods are attached to the hand operating levers of the stokers.

In *Fig. 13* the stokers are installed without any automatic operating device, being operated by the hand lever on the side of the stoker.

In the automatically-operated stoker installations it is possible to operate any one of the stokers independently by hand in case more coal is needed, so that the flexibility of the general system is not impaired by the installation of automatic devices. The general efficiency is, as a rule, slightly better where the automatic devices are employed, as the coal is fed regularly to the fires and the green fuel has time to coke before being forced into the zone of combustion.

It is also true that there is less smoke with an automatically-operated stoker than with the hand-operated. This would not be true if the hand-operated stoker was given the same number of charges, and at equal intervals, as with the automatic device, but where they are hand-operated the operator usually makes three or four charges in close succession and then passes on to another boiler to do the same thing. When the fires are stoked in this way slight smoke can be detected, which indicates, of course, incomplete combustion.

The Committee has had the opportunity of seeing many of these stokers in operation—both hand operated and with the various types of automatics in use. They found, however, that better results were obtained in some plants than in others, due entirely to the way they were operated, but, of course, this is true of any device which depends upon man, in any way, for its operation.

The Committee visited the plant of the Peerless Rubber Company, New Durham, for the purpose of investigating the stokers under consideration.

There are two boiler rooms at this plant, each having four Jones stokers in operation. The west boiler room has four stokers which are actuated mechanically by means of

a horizontal shaft running across the front of the boilers with an eccentric at each stoker, from which a connecting rod is attached to the hand-operating lever of the stoker.

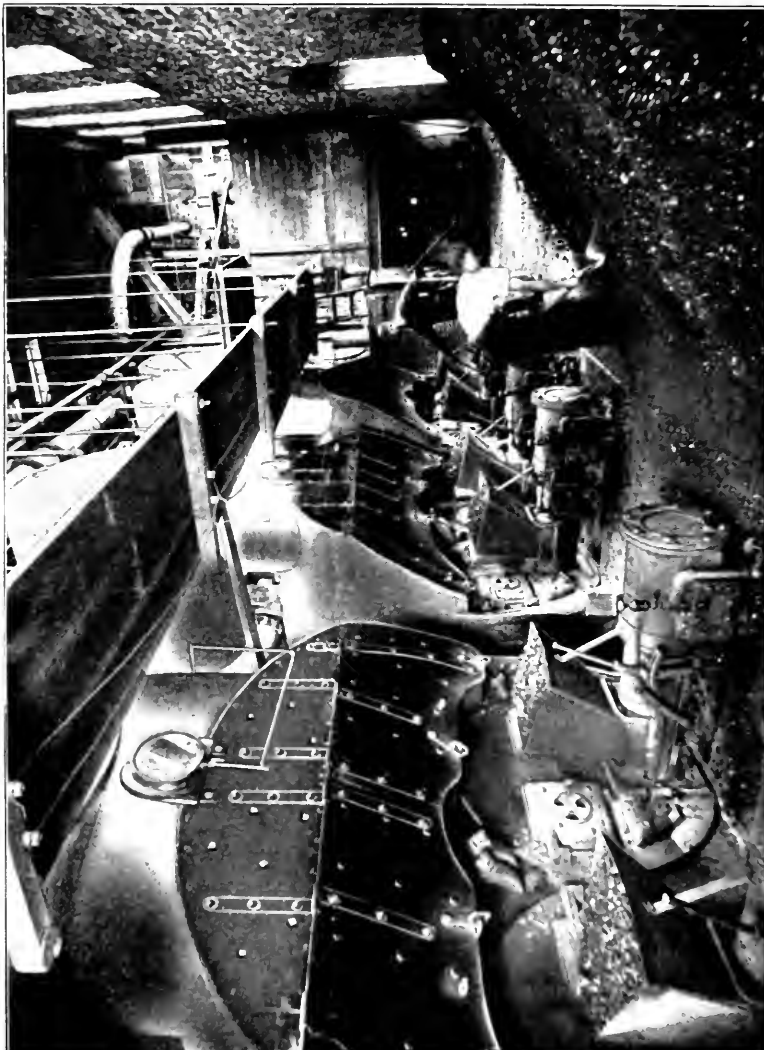

FIG. 13.—Hand-operating stokers.

Such an arrangement is shown in *Fig. 12.* This horizontal shaft is driven by the blower engine (which is a 5 horse-power Case engine) belted to a Sturtevant blower. By this

arrangement the boilers may be run to their utmost by simply regulating the speed of the blower engine. These stokers worked well and the fire was very hot and easily taken care of. We saw one of the fires cleaned, which had been running six hours, and the clinkers and ash which were removed would scarcely fill two shovels. There was practically no combustible left in the clinker or ash removed.

The coal used in this plant is a good grade of bituminous and is shoveled into the stoker hopper by hand. There was no smoke emitted from the stacks. One of the boilers was shut down for cleaning after about a year's run. The fire brick in the furnace was not badly burnt and no repairs in this respect were necessary. On the lower side of the lower tubes there was a deposit of a rather rough, lumpy character, possibly $\frac{1}{4}$ inch thick. This, however, did not extend to any of the tubes above the lower row and was not difficult to remove.

In the east boiler house at this plant there are four stokers of the automatic type with an actuating cylinder attached to the side of the main stoker cylinder, as shown in *Fig. 10*. These stokers worked very well, but there seemed to be some uncertainty about regulating them as to the speed of charging, and in this boiler house we found some combustible in the ash; also a slight amount of smoke was emitted from the stacks, from time to time, due, however, to the inefficiency of the man in charge. In cleaning the fires he drew out some coke and used the poker considerably, which added to the smoke and was entirely unnecessary.

The blower engine in this boiler house was also of 5 horse-power capacity, and during the noon hour the engines were run very slowly, thereby reducing the blast. Also, several charges of coal were forced in which reduced the heat of the fire very rapidly and placed it in a banked condition. The fires are from 12 to 18 inches thick and it is necessary to have the boiler set well above the fire on this account in order to give the gases sufficient time to properly ignite. The distance between the stoker and lower tubes of the boiler should be 4 feet, or thereabouts.

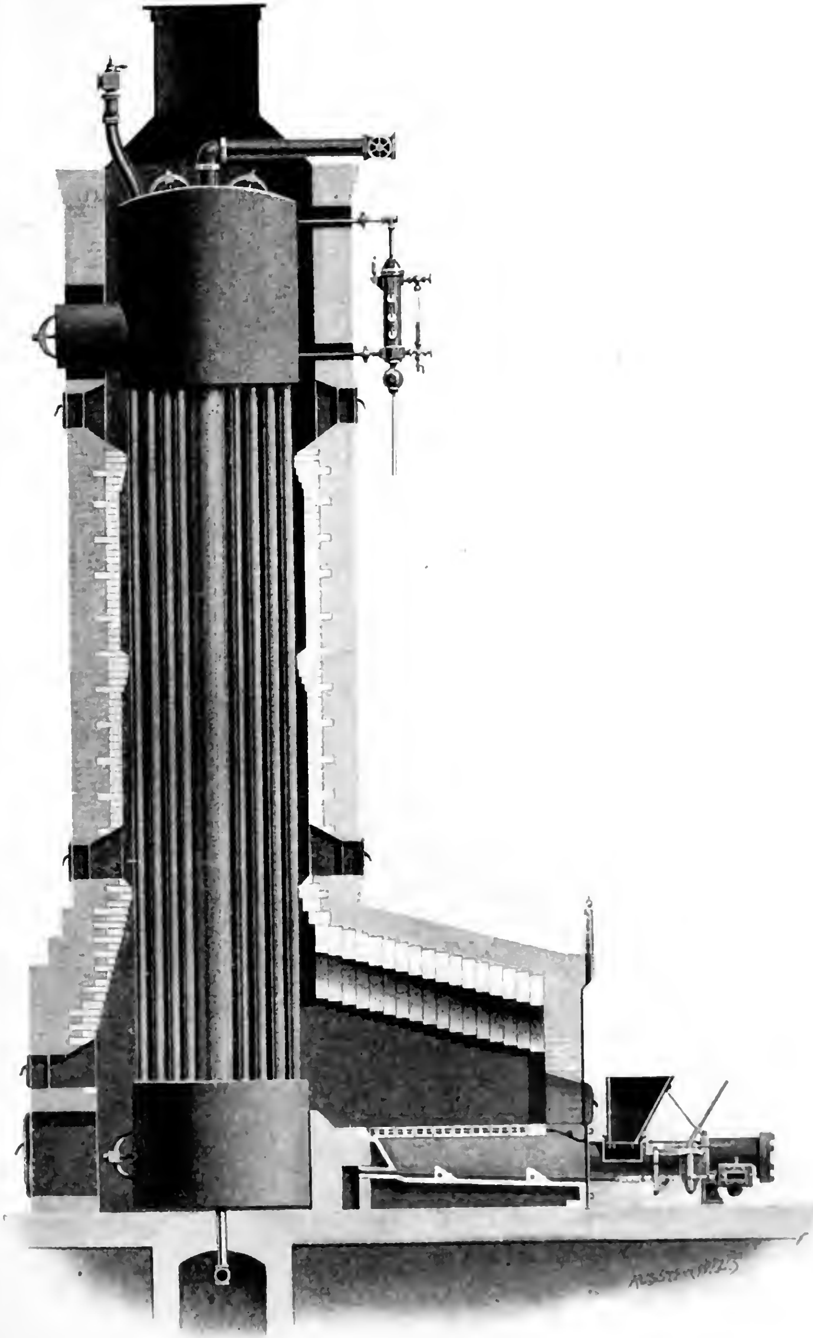

FIG. 14.—Jones stoker under Cook boiler.

The Committee also visited the Hecker plant of the National Biscuit Company, New York, and found there six hand-operated stokers which were firing about thirty-six tons of coal every twenty-four hours, with but one man in the boiler-room. The coal used is a good grade of bituminous slack, and no smoke was emitted from the stack except when the fireman was charging, and then it was very slight. No doubt there would have been no smoke at all had the plant been operated mechanically, as in this case the stoker might take, say, one stroke a minute, while in the case of hand firing the man might wait three or four minutes and then give the stoker as many strokes in close succession, thereby forcing a comparatively large amount of green coal into the fire.

These boilers were being forced and were running night and day. The fires were cleaned but once every twelve hours and sometimes a few clinkers were removed during the day, in case they became large enough to interfere with the fires. Before these stokers were installed the plant had been shut down on many occasions on account of lack of steam, but no trouble is now experienced in this regard. The coal in this plant is fed direct to the stokers by bins and chutes overhead.

The following plants have been visited and a total of thirty-nine stokers have been seen in operation:

The Dominion Wire Company, Montreal.
The Dominion Bridge Company, Montreal.
The Locomotive Machine Company, Montreal.
Grand Trunk Railway, Montreal. (Heating furnaces.)
Place Viger, Montreal.
Eastman Kodak Company, Rochester.
Peerless Rubber Company, New Durham.
National Biscuit Company, New York.
American Bridge Company, Philadelphia.

It will, no doubt, be of interest to see illustrations of applications of this stoker under various types of boilers which are shown herwith.

Fig. 14 shows a hand-operated Jones stoker installed in section of a Cook boiler.

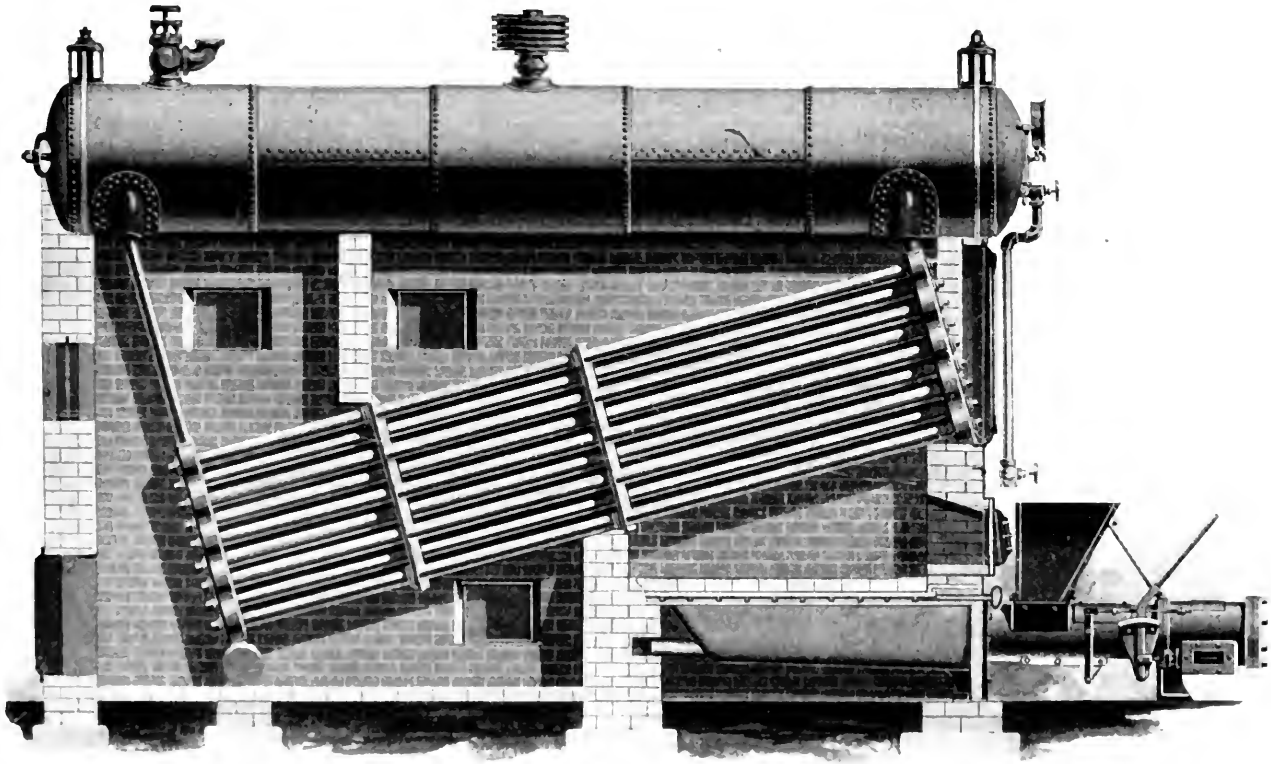

FIG. 15.—Jones stoker under B. & W. boiler.

Fig. 15 shows a Jones stoker installed under a B. & W. boiler with the near wall broken down so that the interior may be seen. Further comment is unnecessary.

Fig. 16 is a Jones stoker installed under a Stirling boiler, which shows the general application in this case.

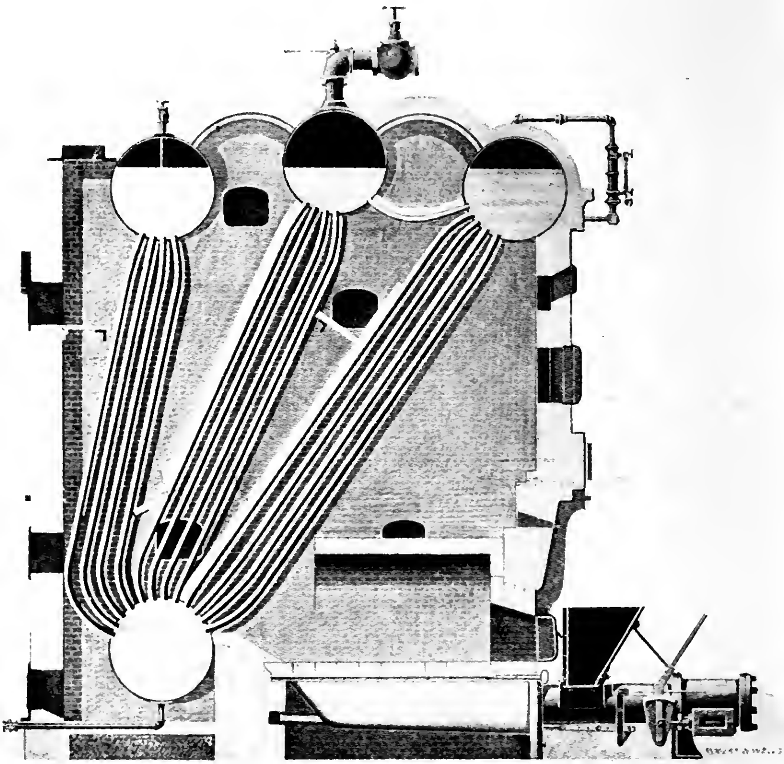

FIG. 16.—Jones stoker installed under Stirling boilers.

As to the matter of efficiency, we append several tables showing tests and data relative to the performance of these stokers.

Table I is compiled by the Portland Cable Railway, Portland, Ore.

TABLE I.

THE FIRST "COMMERCIAL" COMPARATIVE TEST BETWEEN UNDERFEED STOKING AND HAND-FIRING.

OFFICE OF PORTLAND CABLE RAILWAY.

PORTLAND, ORE., March 7, 1892.

DEAR SIR.—The following table will no doubt be of interest to you, as it shows the difference between hand firing and firing with the Jones Mechanical Stoker.

Mechanical Stoker.			*Hand Firing.*		
February 22,	13,940	pounds.	February 29,	17,680	pounds.
" 23,	13,600	"	March 1,	15,640	"
" 24,	13,260	"	" 2,	17,850	"
" 25,	13,260	"	" 3,	22,950	"
" 26,	12,920	"	" 4,	15,300	"
" 27,	13,600	"	" 5,	18,700	"
" 28,	13,600	"	" 6,	18,360	"
Total,	94,180	"	Total,	126,480	"

Hoping that you can see the difference without having to put on your glasses, I remain, Yours respectfully,

R. A. McCLELLAN, Chief Engineer.

These figures were taken at a time when slack and screenings were used in both furnaces. While firing with hand it was impossible to keep up steam, the road being shut down for want of steam at least once a day, every day during the time the hand-fired furnaces were in use. Upon one day (March 3d), five times.

With the stoker, sufficient steam was at all times furnished to operate the road. Saving in fuel, 25·6 per cent.

TABLE II.

STATEMENT OF A COMPARATIVE EVAPORATION TEST (HAND FIRING AND JONES UNDERFEED MECHANICAL STOKERS) UNDER 72-INCH R. F. TUBULAR BOILERS, IN "LAKE SHAFT" PLANT OF THE CLEVELAND IRON MINING COMPANY, ISHPEMING, MICH. ACTUAL COST OF OPERATION OF STOKER GIVEN.

Points Observed.	*Hand Fired*	*Stoker Fired.*
Date of test	October 30, 31,	Nov, 1, 2, 1895
Coal used	Bit. Slack	Bit. Slack.
Duration of tests, *continuous hours*	72	72
Average steam presssure (gauge)	118·95	118·95
Average temperature feed water	210	41·1
Number of boilers in use	2	2
Total pounds coal consumed	50,600	54,864
Total pounds ash and clinker	8,245	8,202·5
Total pounds combustible	42,354	46,661·5
Per cent. ash and clinker	16·27	14·9

Total pounds water evaporated	312,323	341,483
Pounds water evaporated per pound coal at observed temperature	6·17	6·23
Pounds water evaporated per pound coal from and at 212°	6·45	7·57
Pounds water evaporated per pound coal at observed temperature	7·3	7·32
Pounds water evaporated per pound combustible from and at 212°	7·709	8·91
Gain in evaporation		17·37 p. c

NOTE.—Pounds coal consumed in stoker-fired boilers *includes* amount used in fifth boiler to make steam to run blower engine and stoker cylinder. Water evaporated in fifth boiler *not* being included.

This test is a comparative evaporation test, and shows a gain of 17·37 per cent. in favor of the stoker.

TABLE III.

REPORT OF TEST FOR CAPACITY MADE BY TORONTO STREET RAILWAY, TORONTO, ONT., WITH SCOTCH MARINE BOILERS, MECHANICALLY STOKED BY THE JONES UNDER-FEED STOKERS. MARINE BOILER 9 FEET 9 INCHES DIAMETER. TWO 39-INCH CORRUGATED FLUES. INCREASED BOILER CAPACITY 119 PER CENT.

Points Observed.	*Scotch.*	*Scotch.*
Date of tests	Mar. 16, 1900	Mar. 17, 1900
Kind of coal	Pittsburg Mine Run	
Duration of test in hours	5·5	9·2
Heating surface in square feet	1600	1600
Grate surface in square feet	39	39
Average gauge pressure	127	128·3
Average absolute pressure	141·7	143
Average feed temperature, Fahrenheit	142·2	143·8
Average temperature of escaping gases, Fahrenheit,	376	380
Total amount of coal burned, in pounds	7425	12497
Total refuse	558	1017
Percentage refuse	7·51	8·14
Coal burned per boiler per hour, in pounds	1325	1351+
Coal burned per square foot of original grate surface per hour	34	34·6
Total weight of water fed into boiler at actual temperature of feed	60215	100467
Total equivalent from and at 212° F., fed into boiler and apparently evaporated	67302	112151
Equivalent hourly evaporation from and at 212°	12054	12103
Water actually evaporated per pound coal, in pounds	8·11	8·039
Equivalent evaporation from and at 212°, per pound coal	9·064	8·974

Actual evaporation per pound combustible	8·769	8·751
Equivalent evaporation from and at 212° per pound combustible	9·801	9·769
Heat given to every pound of water to evaporate the same into steam at boiler pressure, B.T.U. . . .	1079·6	1078·2
Heat transmitted to feed water per pound combustible	9468	9436
Horse-power developed (34½ pounds from and at 212°)	346·5	350·8
Rating of boilers (Builder's)	160	160
Water evaporated from and at 212° per square foot of grate surface	7·534	7·564
Heating surface per horse-power of 34½ pounds . .	4·62	4·56
Percentage increase in capacity over hand firing, taking Barrus test of August, 1895, as standard .	73 p.c.	75 p.c.
Increase over Builder's rating	116·6 p.c.	119·2 p.c.

Test given in Table III was made for capacity with Scotch marine boilers, 9 feet 9 inches in diameter, with two 36-inch corrugated flues. This test shows a very large increase in capacity over the builder's rating, as well as over the capacity when hand-fired in August, 1895.

TABLE IV.

TEST MADE UNDER ORDINARY WORKING CONDITIONS AT THE TORONTO ELECTRIC LIGHT COMPANY'S TERAULEY STREET STATION BETWEEN JONES UNDERFEED STOKERS AND HAND FIRING. TEST MADE AFTER FAILURE OF OTHER FURNACES TO SHOW ANY SAVINGS.

Points Observed.	*Jones.*	*Hand.*
Date of test	September, 1897.	
Kind of boiler	Babcock & Wilcox, Water Tube, 212 H. P.	
Kind of coal	"Reynoldsville" Screenings.	
Duration of test, hours	18	18
Total coal burned in pounds	13600	15000
Total water evaporated, pounds	126113	112338
Average steam pressure, pounds	158	158
Average feed temperature, degrees	145	145
Actual evaporation per pound coal from temperature of feed water	9·227	7·489
Equivalent evaporation per pound coal from and at 212°	10·3342	8·38768
Relative evaporation	123·2	100

Showing 23·2 per cent. increase in efficiency.

This test at Toronto Electric Light Company's Terauley Street Station shows an increase in efficiency of 23·2 per cent.

Of course, we all appreciate how difficult it is to obtain reliable data on boiler tests, but the showing in all cases with the stoker under consideration comes up so very well that it is only fair to assume that there must be considerable gain on all the points considered. We have records of many more such tests, but do not feel that it is advisable to embody them in the report.

In regard to patents, we find that the following bear on the subject in hand:

409,792.	E. W. Jones	August 27, 1889.
470,052.	" " "	March 1, 1892.
470,053.	" " "	" " "
569,207.	" " "	October 13, 1896.
595,837.	J. M. Roe	December 21, 1897.
464,664.	F. A. Daley	March 6, 1900.

The first patent, No. 409,792, E. W. Jones, August 27, 1889, covers the fundamental principle of the stoker. We will quote some of his claims as follows:

(1) A furnace provided with a lateral fuel-supply opening beneath the fire, a supporting bottom for the fire, sloping upward and backward from the supply opening, grate bars forming a portion of said bottom, a dead plate forming the remaining portion of said bottom, and a ram on the side of the furnace for forcing fuel into the opening, whereby fuel may be readily pushed up into the fire and will be firmly supported independently of the position of the feeding mechanism.

(4) A furnace provided with a fuel chamber having an upwardly-inclined side and a fuel-supply opening below the line of fire, means for forcing fuel up into the chamber, and air-supplying grates in the side or sides of the chamber.

(9) In a furnace the combination of a fuel chamber having an upwardly-inclined bottom and a fuel-supply opening opposite said bottom below the line of fire, and a ram for forcing fuel into the opening, said ram having a fire-brick lining on the side entering the opening.

The second patent of Mr. Jones, 470,052, March 1, 1892, covers some of the details in the refinement of the apparatus, such as operating lever and valves, construction of ram and arrangement of air openings in the retort.

The third patent of Mr. Jones, 470,053, March 1, 1892, covers details in connection with the arrangement of grate bars for wood-burning, and is an improvement on his furnace 409,792. This patent, however, relates particularly to a retort having grate bars and taking air over the entire surface of it, while the later forms do not have this arrangement.

Mr. Jones' fourth and last patent, 569,207, October 13, 1896, relates to improvements in furnaces, with special reference to patents 409,792 and 470,053. He claims in this some slight improvements in shape of retort, such as flaring sides, etc. The arrangement of the valve-operating mechanism on the cylinder and the construction of the ram case, none of the changes being radical except the last claim, as follows:

(10) In an underfeed furnace with a fuel opening below the line of fire, a magazine gradually decreasing in depth toward the rear, and provided with a curved or inclined bottom and horizontally-attaching flanges to its upper edges provided with longitudinal slits to permit expansion and contraction, and an air-distributing pipe for forcing air over the top of the fire, and a ram or plunger for forcing the fuel into the magazine, substantially as described.

Patent 595,837, by J. M. Roe, December 21, 1897, relates to improvements in furnaces, and particularly to improvements in combination with an underfeed mechanical stoker of the type heretofore patented to Evan W. Jones in patents 409,792 and 470,052, to which this patent specifically refers. His patent covers the pusher bar with the pushers to aid in pushing the coal to the rear of the retort, making an even distribution more certain than by inclined hopper, as originally adopted by Mr. Jones. His patent also covers the system of varying the stroke of this pusher rod, as described in the early part of this report. It is an improvement on Mr. Jones' patents, and is not fundamental in regard to underfeed stoking or the design of stoker under consideration.

U. S. patent No. 464,664, to F. A. Daley, March 6, 1900, covers the details in connection with the tuyere blocks and

dead plates on either side of the retort. His first claim is as follows:

(1) In a furnace the combination of a fire-box of an elongated, horizontally-disposed fuel retort, dead plates upon each side of the retort, said retort and dead plates serving to afford a sealed space beneath the fire-box and retort, tuyere openings provided along the longitudinal sides of the retort, and affording communication between the fire-box and the space beneath the same and means for forcing air under pressure into the space beneath the fire-box, substantially as described.

In view of the fact that Mr. Evan William Jones has done such good work in bringing out the design of underfeed stoker under consideration, and in view of the simplicity of the device from a mechanical standpoint, both in construction and operation, we recommend that the John Scott Legacy Premium and Medal be awarded to him.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, February 3, 1904.

Attest: WM. H. WAHL,
Secretary.

MAGNETITE ARC LAMP.

C. P. Steinmetz has discovered that magnetite, the black oxide of iron, is suitable for use as an electrode in an arc lamp. From investigations which have been made with different materials, it appears that the arc flame issues from the negative terminal, and striking the positive produces heat. If the positive electrode cannot convey the heat away fast enough, it becomes hot, as in the case of the carbon arc. For this reason the flame-coloring substances are introduced into the positive electrode in the Bremer and other lamps. In the magnetite lamp the positive electrode is a copper segment, which is of such size that it does not get too hot, and therefore does not wear away, forming a permanent part of the lamp.

EMPLOYEES IN THE KRUPP STEEL-WORKS.

United States Consul-General Richard Guenther, Frankfort, Germany, reports, under date of July 21st, that, according to the published statement of the Krupp Works, the total number of persons employed by the firm on April 1, 1904, including 4,190 officials, was 45,289. Of these the cast-steel works at Essen employed 25,041; the Gruson Works at Buckau, 3,329; the Germania shipbuilding yard at Kiel, 2,811; the coal mines, 7,877; the iron mines, etc., 6,231 persons.

Obituary.

THOMAS MESSINGER DROWN.

Thomas Messinger Drown was born in Philadelphia, March 19, 1842, and died in Bethlehem, Pa., Friday, November 18, 1904, in his sixty-third year. He was the son of the head of the firm of Drown & Co., the largest manufacturers of umbrellas in his native city, with an extensive shop in lower Market Street. He graduated at the Philadelphia High School in 1859, and from the medical department of the University of Pennsylvania in 1862, Prof. Robert E. Rogers having at that epoch the chair of chemistry in the medical course. He continued his studies in chemistry at the Sheffield Scientific School of Yale, and both at the Lawrence Scientific School of Harvard, and at the Boston Institute of Technology, for three years, finally passing the years 1865 and 1866 at the Academy of Mines in Freiberg, Saxony, and subsequently at Heidelberg.

The writer of these lines met him for the first time at Freiberg in 1866, and occupied the thoroughly student-like suite of a study and sleeping-room which Dr. Drown was just vacating.

The acquaintance begun in Germany ripened into warm friendship in this country on the present writer's return to Philadelphia in 1870, after four years passed in Germany and with Dr. Hayden's Geological Survey of the Territories. In 1871 Eckley B. Coxe, R. P. Rothwell, and Martin Coryell sent out a circular dated April, 1871, to numerous persons interested in mining and metallurgical affairs, which resulted in the reunion of twenty-two men, of whom Dr. Drown was one, at Wilkesbarre, Pa., on May 16, 1871. This was the foundation of the American Institute of Mining Engineers. In May, 1873, Dr. Drown was elected secretary of the Institute, and held the position till the annual meeting of 1883, fulfilling its duties in the most admirable manner. Previously to this, during 1869–70, he was an instructor in metallurgy at Harvard, and during his

early incumbency as secretary he maintained an analytical laboratory in Philadelphia, but in 1874–81 filled the chair of chemistry in Lafayette College, Easton, Pa. From 1885 to 1895 he was Professor of Chemistry at the Massachusetts Institute of Technology, and from 1887 in charge of the chemical department of the Massachusetts State Board of Health. In 1895 he was elected President of Lehigh University, which position he held till his death.

The above are the bare facts of Dr. Drown's career, from which, however, it is not difficult to conclude that he had in large measure those qualities which ensure their possessor "honor, love, obedience, troops of friends." The conclusion is amply justified, but it is not the whole truth. It is difficult to say whether Dr. Drown impressed one more by his gentle, courteous manner; his persuasive, low, musical voice; his constant good temper and fine sense of humor, or by his rigid scientific method of view; his exhaustive knowledge of the subject considered in his reports and lectures; and his clear exposition of them. Everybody was his friend. He had no enemies, and he deserved none. Without compromising his loyalty to a friend, he had that valuable faculty of evading dissensions, which was so noticeable in the late Dr. Joseph Leidy. But if he never aggravated an irritation, he succeeded very frequently in bringing peace and reconciliation to the heated disputants. Nothing unkindly ever passed his lips, but they uttered countless phrases of wisdom, wit and good will. Dr. Drown was, in the highest sense of the words, a thoughtful and profound scholar; a gentle, sympathetic and happiness-diffusing friend, and a Christian gentleman.

PERSIFOR FRAZER.

PHILADELPHIA, November 22, 1904.

Notes and Comments.

ARTIFICIAL COTTON IN FRANCE.

The French Chamber of Commerce of Milan says that an artificial cotton is now made from the cellulose of the fir tree freed from bark and knots. The fibers after being pulverized by a special machine, are placed in a horizontal brass lead-lined cylinder of some 3,500 cubic feet capacity and steamed for ten hours, after which 2,000 cubic feet of a bisulphate of soda wash is added and the whole is heated for thirty-six hours under a pressure of three atmospheres. Then the wood, or fibre, which has become very white, is washed and ground by a series of strong metallic meshes, after which it is again washed and given an electro-chemical bleaching by means of chloride of lime. Passing between two powerful rollers then dries the matter, producing a pure cellulose, which when reheated in a tight metal boiler containing a mixture of chloride of zinc and hydrochloric and nitric acids, to which is added a little castor oil, casein, and gelatine to give resistance to the fibre, gives a very consistent paste. Threads are then produced by passing this paste through a kind of draw-plate. These threads, after being passed over a gummed cloth, are immersed in a weak solution of carbonate of soda and passed between two slowly-turning drying cylinders. Finally, to give the necessary solidity, the thread is treated to an ammoniacal bath and rinsed in cold water, after which the product is pliable and works well.

In Bavaria experiments have recently been made to produce cotton from pinewood, and it is claimed that the trials have been very successful.—*Scientific American Supplement.*

KAPOK AND ITS USES.

Every year that busy center of commerce, Amsterdam, receives nearly 1,000 pounds' weight of a curious and interesting vegetable substance known in Java and in the trade as kapok, which is found very useful for stuffing cheap mattresses and pillows among other purposes. It is a sort of yellow wadding which nature uses as a covering for the seeds of certain trees in the Malaccas, Its fibers being very non-resistant, it has been found impossible to spin or weave it, but it gives excellent results for bedding, making a mattress delightfully soft if it is exposed to the sun before being used. It is exceedingly light and buoyant, in this respect greatly surpassing cork, as it will support in the water thirty-five times its own weight. The tree whence it is derived (*Eriodendron*) grows rapidly, and in the second year is 12 to 15 feet high. but it does not fruit abundantly until the fourth year. Like the cotton plant, it bestows two gifts on man—the special wadding mentioned, which lines the husk, and the oil extracted from the seeds, which is used especially in the Chinese markets. The threads of the soft fiber taken from the pods are light yellow, rather silky, and only about an inch in length. They are made into thin rings. Kapok, it is said, never decays. Among the ever-increasing uses to which this curious vegetable product is put—causing the culture of the Eriodendron to make great strides in the Dutch Indies, while efforts are being made to cultivate it in similar climates—it has been suggested that excellent life-saving

apparatus might be made from it, which should be in the form of mattresses and cushions, easily obtainable in moments of danger. Three hundred grams of kapok (10¼ ounces) will support a man of 10 stone 5 pounds (145 pounds) in the water; and experiments by a French society with articles made of this wadding, which had previously been soaked in water for eighteen hours, gave excellent results. One small mattress supported several men. It is probable that soon all ships' beds will be made of kapok.—*Chambers's Journal.*

GARNET FOR ABRASIVE PURPOSES.

The use of garnet as an abrasive has found a flattering reception among manufacturers; and while it meets the competition of quartz, corundum, crushed steel, and carborundum, these materials have not limited or decreased its popularity. According to the report of Mr. Pratt in the Mineral Resources of the United States for 1902, the total value of all natural abrasives produced in the United States for that year was $1,326,255, and of this amount $132,820 was represented by garnet, as against $104,605 for corundum and emery.

Local shipping conditions influence the success of quarries of abrasive substances intimately. The Montana corundum deposits were practically shut out from the general market because of prejudicial freight rates. When these were removed, or modified, they began, in July, 1903, to produce raw material at the rate of from 800 to 1,000 tons per year.

Mr. Pratt says that in 1902 the production of corundum in the United States was almost entirely of the emery variety. It was confined to Chester, Mass., and Peekskill, N. Y., the latter locality greatly increasing its output. The Canadian corundum is very largely imported into the United States, and this importation quite steadily increases. The total amount of commercial corundum produced in Canada in 1902 was 1,611,200 pounds, valued at $88,616, or nearly $110 per ton. It, for the most part, leaves Canada, and the United States is her largest customer.

Garnet as an abrasive has a good market. New localities of this material of fine quality and in accessible situations cannot fail to attract notice and reward development. An apparently rich deposit of garnet has been recently brought into business prominence, which is located on little Pine Creek, Little Pine Creek Township, Madison County, North Carolina.

The garnets occur in a chloritic schist well developed and in large aggregates. They are the iron alumina variety—almandine—and not infrequently present superb gem surfaces, which furnish very superior cuttings.

The prospecting of this property began in January, 1904, and after the work of a month over 20 tons of good merchantable garnet was cleaned up. Work was resumed in March and continued for two months. In this period over 160 tons were mined and 140 tons shipped. The garnet is pronounced to be an excellent abrasive. The property promises important results, and will naturally attract some attention. The garnets resemble the famous Salida, Colo., specimens, and furnish attractive mineral groups.

The company now engaged in the exploitation of this property is the North Carolina Garnet Company, incorporated under the laws of New York State.

ALUMINUM CONDUCTORS.

In a paper read before the Canadian Electrical Association, Mr. Roderick J. Parke contributes some valuable information relating to the use of aluminum for electrical conductors. As compared with copper, the cost of transportation and erection of aluminum conductors is less, the durability greater and the cost of maintenance less; but these advantages are counterbalanced by difficulty in making joints, great sag due to large co-efficient of expansion and insufficient strength of the wires in sizes ordinarily used for telegraph and telephone lines. The following data are of assistance in showing the relative merits of commercial aluminum and commercial (hard drawn) copper, of sizes ordinarily used for conductors:

	Aluminum.	Copper.
Specific gravity	2·68	8·93
Conductivity	62·00	97·00
Tensile strength (per square inch)	28,000	45,000
Cross-section for equal resistance	1·56	1
Diameter for equal resistance	1·25	1
Weight for equal resistance	0·47	1
Tensile strength for equal resistance	0·96	1

The difficulty of soldering aluminum is well-known, and, while it can be done, the operation is so difficult that in most cases unsoldered joints are preferable. For joining aluminum wires smaller than No. 0000 (B. & S. gauge), the two ends are inserted into a piece of flattened tube and the tube given 2·5 twists by means of two pairs of ordinary wire connectors. Larger sizes can be conveniently joined by means of the ordinary dovetailed splice, by means of terminals compressed on the ends at the factory, or by inserting the ends into a cast sleeve and compressing the latter in a portable press.

Book Notices.

Types and Details of Bridge Construction. Part I. Arch Spans. Examples of constructed, wooden, combination, wrought iron and steel arches for highway and railroad bridges By Frank W. Skinner, M. Am. Soc. C. E., etc., etc. 8vo, pp. 289. New York: McGraw Publishing Company. (Price, $3.00.)

The author explains in his prefatory remarks that his object has been to present in this work the development of advanced practice and its standard details, to illustrate the classes of structures adapted to different conditions, to show some of the characteristic differences between American and foreign design, and to illustrate some primitive or obsolete constructions, besides recording important and well-known examples so as to have their principal data easily accessible.

The subject is treated under the following heads: Part I.—Wood and Iron Arch Spans. Part II.—Spandrel Braced Arches. Part III.—Arch Trusses. Part IV.—Plate Girder Arches.

The work is elaborately illustrated, and is intended for students, instructors, designers, engineers, architects and contractors. W.

Das königliche Material-Prüfungsamt der Technischen Hochschule Berlin auf dem Gelände der Domäne Dahlem beim Bahnhof Gross-Lichterfelde, West. Denkschrift zur Eröffnung bearbeitet von dem Director A. Martens, Professor und Geheimer Regierungsrath, und M. Guth, k. Landbauinspector. Mit zahlreichen Textfiguren und 6 Tafeln. Large 4to, pp. 380. Berlin: Verlag von Julius Springer, 1904.

The above-named volume forms an imposing memorial of the opening of the splendidly-equipped Department for Testing Materials of the Technical High School in Berlin. Every branch of this extensive establishment is described and illustrated in elaborate detail. W.

Wireless Telegraphy; its origin, development, inventions and apparatus. By Charles Henry Sewall. With eighty-five diagrams and illustrations. 8vo, pp. 229. New York: D. Van Nostrand Company, 1903. (Price, $3.00.)

This is a very timely publication, covering the history, systems, principles and possibilities of wireless telegraphy in theory and practice. The book is free from abstruse mathematics, and should be of service both to layman and student. W.

National Conference on Secondary Education and its Problems, held at Northwestern University, October 30 and 31, 1903. Stenographic report of the proceedings, edited by V. K. Froula. Published by the University, Evanston, 1904.

This conference was called by Northwestern University to meet at Evanston, Ill., October 30 and 31, 1903. The meeting appears to have been a very successful one, there being present and participating representatives of twenty-five States.

The stenographic report of the proceedings of the conference, edited by Mr. Froula, makes an octavo volume of 256 pages. The scope and character of the discussions will be understood from the following list of subjects:

I. "What is the place and function of the endowed academy, or of the private high school for boys and girls in our present system of education?"

II. "What is the true function of the public high school?"

III. "What is the effect of the system of accrediting schools by the universities upon the high school and its development?"

IV. "What may the public high schools do for the moral and religious training of its pupils?"

V. "Some serious defects in our high school system."

VI. *a.* "Are there too many women teachers in the schools?"

b. "How may we counteract the growing encroachment of social life upon serious study?"

c. "How shall we remedy the tendency to imitate questionable features of college life, such as fraternities, excessive development of competitive sports, etc., etc."

VII. Addresses by Congressman Boutelle upon the "American High School as the Training Place for Citizenship," and by Professor Fisk on "Where to Place the Emphasis in Secondary Education." W.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, November 16, 1904.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 16, 1904.

PRESIDENT JOHN BIRKINBINE in the chair.

Present, 160 members and visitors.

Additions to membership since last report, 10.

The chairman introduced Dr. Z. B. Babbitt, of the American Telegraphone Company, of New York, who read a paper describing the invention of Valdemar Poulson, of Copenhagen, Denmark, known as the "Telegraphone," by which the sounds of the human voice are recorded on a metal wire or disk—without indentation or mark of any kind—by electro-magnetic means, and may subsequently be reproduced audibly through the telephone an indefinite number of times with extreme fidelity, or, if desired, may be destroyed by similar means. The subject of the invention was, on motion, referred to the Committee on Sciences and the Arts for investigation and report.

Dr. Babbitt, at the close of the meeting, gave a demonstration with the machine.

Dr. Henry Leffmann, by special request, presented some interesting reminiscences of "Washington as an Engineer," and illustrated his remarks by exhibiting a series of lantern views of a number of drawings of land surveys, etc., made by Washington.

The thanks of the meeting were voted to the speakers of the evening, and the session was adjourned.

WM. H. WAHL,
Secretary.

Committee on Science and the Arts.

(*Abstract of the proceedings of the stated meeting, held Wednesday, November 2, 1904.*)

PROF. LEWIS M. HAUPT in the chair.

The following reports were adopted:

(No. 2318.) *Suction Gas Producers:* Otto Gas Engine Company.

This apparatus apparently cannot be considered as a single invention, being, in fact, the completed result of a series of improvements made in the various branches of the extensive Otto Gas Engine Company.

The present invention is a simplified apparatus for making producer gas for use in gas engines. With this apparatus the use of a gas-holder is dispensed with, the gas being produced just at the rate at which it is needed. It consists substantially of a furnace or producer and a scrubber.

The lower portion of the producer contains the fire-box. The ash-box below the grate is enclosed so that the air can be admitted only through a passage to be described below. Air-tight doors permit of access to the grate for stoking, raking and removing ashes.

An annular water-jacket is placed above the fire-box, by which the gases

from the furnace are cooled before they enter the pipe leading to the scrubber. The jackets also serve to saturate the air with steam before it is led below the grate.

Above the jacket there is a coal magazine which is filled from time to time, and from which the coal passes through the central opening of the jacket as the coal in the fire-box is consumed. The cover of the magazine, which is practically air-tight, has a central orifice closed by a spherical valve through which a stoker can be thrust for the purpose of stoking the fire when necessary, practically excluding the air during the process.

The scrubber is a vertical drum filled with broken coke over which water is sprayed. The gas, passing upward through this, is cleansed of dust and of all admixed gases which are soluble in water, such as sulphuretted hydrogen that may form in the presence of sulphur in the coal.

From the scrubber the gas is led to the engine, where it is mixed with air, in the usual way, to produce the explosive mixture.

In starting the fire the combustion gases are led to the chimney, an artificial draft being produced by means of a fan driven by hand. After the fire is in proper condition, access to the chimney is closed and the gas is admitted to the scrubber. Raking and stoking should be done about every two hours. The air admitted to the fire through the ash-doors, while this is being done, has no noticeable effect on the quality of the gas. As this air is not saturated with steam, the gas then produced will, of course, be free from hydrogen, and will contain a relatively greater percentage of nitrogen.

For this reason the raking should be done without needless loss of time, and the doors promptly closed. A fresh fire is found to be advantageous about once a week to prevent the accumulation of clinkers. Over night the fire is maintained by banking and making connection with the chimney.

The report here gives the results of the test of one of these suction producers in the works of Hugo Bilgram, made by Messrs. E. B. Myers and H. D. Pratt, students at the University of Pennsylvania, under the supervision of Prof. H. W. Spangler.

From this test it appears that the coal consumption per indicated horse-power was 1·48 pounds, or, adding the proportional share of coal used to start the fire, 1·88 pounds per indicated horse-power. The test was made under rather unfavorable conditions. The mean performance during the test of engine, rated at 48 brake horse-power, if fed with producer gas, was only 25·3 indicated horse-power. Under these conditions it is obvious that the efficiency of the engine was not as high as it would have been had the engine been used more nearly at its maximum performance.

The committee concludes that the efficiency of the engine supplied with a suction producer is far higher than that of steam engines of equal power; and, since it also requires less attention, it seems to be the least expensive of the prime motors where natural agents, such as waterfalls or natural gas, are not available.

Sub-Committee: Hugo Bilgram, Chairman; J. M. Emanuel, John Haug.

(No. 2284.) *Wire-Testing Machine.* Falkenau-Sinclair Machine Company, Philadelphia.

ABSTRACT: The principal feature of this machine is the provision for conducting a bending test while the test-piece is subject to a tensile stress, which

enables the specimen to be tested under approximate working conditions. The usual method of determining whether a coil of iron or steel wire or cable comes up to requirements, after a preliminary examination of its size and general appearance, is to first ascertain its ultimate strength and elongation from test-pieces cut from each end. If the result is in accordance with requirements, a bending test is made, the test-piece being clamped between jaws and bent repeatedly through an arc varying from 90° to 180°. No tension is applied during bending, the number of bends that the wire is capable of withstanding without fracture determining the approximate quality of the metal.

A torsional test is frequently called for in specifications in which a certain specified number of twists are required in specified lengths; and not infrequently, other requirements are specified which are impracticable and inconsistent. All of which indicates the need of standard methods and improved apparatus for wire-testing purposes.

The report proceeds to say that the Falkenau-Sinclair machine is an advance step in this direction, though it is still open for improvement. Then follows a detailed mechanical description of the construction and operative features of the machine, which would not be intelligible without the aid of illustrations. Reference to the patent is made, to wit: Lee C. Moore, Brooklyn, N. Y.; U. S. Patent No. 673,526, May 7, 1900; and to the following claims of same, which will be generally explanatory:

"Claim I. In a metal-testing machine the combination of devices for applying tensile strain to the metal and for repeatedly bending the same in reverse directions while under tensile strain, and of devices for registering the extent of the stretch of the metal as strained and bent for the purposes set forth.

"Claim II. In a metal-testing machine the combination of two sets of jaws adapted respectively to grip the end of the metal being tested, one of the pairs of jaws being movable longitudinally away from the other pair, and the latter pair being pivotally supported at a point lying between the said pairs of jaws, an additional pair of clamping jaws adapted to clamp the metal when stretched between the said stretching jaws, and means to register the amount of strain applied to the metal by the stretching jaws, for the purposes set forth."

The report concludes in the following terms: "In view of the fact that Mr. Lee C. Moore has brought out a labor-saving device that is an improvement over other types in that the tensile and bending tests can be determined simultaneously under approximately working conditions, and in view of its simplicity of construction from a mechanical standpoint, we recommend the award of the John Scott Legacy Premium and Medal. (*Sub-Committee*, Kern Dodge, chairman; Charles E. Ronaldson.)

The following reports passed first reading:

(No. 2312.) *Cap-Screws and Bolts.* Cleveland Cap-Screw and Bolt Company, Cleveland, O.

(No. 2327.) *Glazier's Fire Nozzle.* Bradley & Munson, New York.

(No. 2331.) *Electric Protective Devices.* International Burglar Immunity Company, Philadelphia.

(No. 2350.) *Instantaneous Automatic Water Heater.* Rue Manufacturing Company, Philadelphia. W.

Sections.

Section of Photography and Microscopy.—*Stated meeting*, held Thursday, November 3d. Dr. Henry Leffmann in the chair. Present, 63 members and visitors.

Mr. John Bartlett, of Philadelphia, presented a paper on "Photographic Art and Motion." The speaker's remarks were profusely illustrated by the exhibition of a series of lantern photographs of famous pieces of statuary and paintings, as well as by views from nature. The speaker's contention was that by proper attention to correct rules of art, photographers might greatly enhance the artistic effect of their productions.

Dr. Leffmann followed with some informal, but highly interesting, remarks on "Washington's Work as an Engineer," which he illustrated by several photographs of survey maps, sketch maps and mathematical exercises, the originals of which, in Washington's own hand, are preserved in various collections.

Following the regular business of the evening, a communication was read from Mr. Walter Zimmerman, containing a proposition that the Franklin Institute inaugurate a system of collecting, cataloguing and preserving photographs of historic interest, in conjunction with the American Federation of Photographic Societies.

The Section voted to refer this communication to the Board of Managers of the Institute with a favorable recommendation, and the Executive Committee of the Section was directed to confer with the Board in the consideration of the subject.

The chairman thereupon adjourned the meeting.

M. I. Wilbert,
Secretary.

Chemical Section.—*Stated meeting*, held Thursday, November 10th, 8 P.M., Dr. W. J. Williams in the chair. Present, 15 members and visitors.

The papers of the evening were as follows:

Dr. J. Merritt Matthews on "Sulphur Dyes."

Dr. E. Goldsmith on "Salt Making in the Far West."

Both were freely discussed, and will appear in due course in the Journal.

W. E. Ridenour,
Secretary.

Mining and Metallurgical Section.—*Stated meeting*, held Thursday, November 17th, 8 P.M. Mr. C. H. Clamer in the chair. Present, 29 members and visitors.

The chairman introduced Mr. Paul Kreuzpointner, Superintendent of Tests, Pennsylvania Railroad Company, Altoona, Pa., who read a paper on "Metallurgy in its Relations to Industrial Education."

Dr. Geo. P. Scholl gave a communication on "The Manufacture of Ferro-Alloys."

Both communications were freely discussed.

The chairman tendered the thanks of the meeting to the speakers of the evening.

Wm. H. Wahl,
Secretary pro tem.